A HAND-BOOK OF BOTANY FOR INDIA

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BY

DEWAN BAHADUR K. RANGACHARI, M.A., L.T.

Indian Agricultural Service (Retired)

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PREFACE

THE number of students studying botany is gradually increasing. Books on botany now in common use are not suited to the requirements of the Indian student, as the plants referred to in many of these books are foreign ones not known to him. The few books in which Indian plants are dealt with cover only certain aspects of plant life, and too much prominence is given to the study of Natural Orders or Families.

This book is intended to meet the requirements of University students in their Intermediate and pre-graduate courses and those of the professional Colleges such as the Medical, Agricultural and Forest Colleges. It will also be found useful to persons interested in the study of plants. The scope and arrangement of the topics adopted is based upon my experience as a teacher and examiner for the Madras University Examinations for nearly a decade.

I have to express my thanks to Mr. Rudolph D. Anstead Director of Agriculture, Madras Government and the Government of Madras for giving me permission to reproduce the illustrations mentioned below from my published books (Figs.—4, 11, 13, 21, 24, 43, 52, 82, 83, 114, 134, 145, 148, 150, 159, to 162, 164, 165, 167, 170, 173, 174, 175, 181 to 185, 188 to 190, 193, 198 199, 203, 209 to 214, 217 to 220, 228 to 230, 253, 258 to 260, 262, 264 to 274, 278, 280, 282, 283, 294, 295, 298 to 300, 303. to 305, 307, 308, 318, 322, 328, 329, 331, 332, 335, 350, 351 353, 357, 361, 362, 364, 267, 372 to 374, 375). The illustrations of the following figures are from photographs kindly given by Mr. M. O. Parthasarathy Aiyangar, Professor

of Botany, Presidency College, Madras to whom I am also indebted for some suggestions.—Figs. 32, 35, 64, 275 to 277, 288, 296, 297, 301, 302, 376—380, 382, 384 to 387. The photomicrographs of Figs. 106, 107, 151, 153, 155, 156, 157, 176, 287, are from slides prepared and kindly lent by Dr. M. A. *Sampathkumaran*, Professor of Botany, Central College, Bangalore. I am indebted to Mr. R. Debberman, Botanic Gardens, Calcutta, for Fig. 28 and to Mr. C. Tadulingam, Lecturing Botanist, Agricultural College, Coimbatore for Figs. 235, 236 and 356. The Figs. 355, 360 and 368 are reproduced with the kind permission of Dr. F. H. Gravely, Superintendent, Government Museum, Madras, from the collection of excellent drawings specially prepared for the Flora of Madras City, to be published shortly.

I regret that owing to certain circumstances which could not be controlled some errors have crept in and so an errata list had to be issued.

I have to thank Mr. M. S. Sabesa Iyer, M.A., of the Madras Christian College for assistance in proof-reading.

April, 1925
Madras

K. RANGACHARI

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SECTION I
MORPHOLOGY

AGRICULTU... COIMBATORE

A HAND-BOOK OF BOTANY

CHAPTER I

INTRODUCTION

THE science of plants or botany is a very important and interesting branch of knowledge. Plants form the basis, as it were, of all life. From a study of plants we learn something about life. The uses of plants to human life are indeed manifold. Every human being, therefore, should possess a knowledge of at least the fundamental features of plant life. The importance of this knowledge to men who follow the professions of agriculture, forestry and medicine is too well known to need any mention.

Plants are living beings, and this fact should never be forgotten. Ordinarily we are most familiar with the higher plants and they live on the land. These plants are, on the whole, though by no means invariably, bigger than the lower, less complex forms. In the vast vegetation clothing the earth's surface we find endless variations in size. Some plants are so small that they cannot be seen with the naked eye. Side by side with these we have small plants, such as grasses and herbs and large plants, such as the tamarind, the banyan and the palm trees.

All plants, whatever their size, high or low, live and

reproduce themselves, just as animals do. These two great functions are of the utmost importance to all living organisms.

Plants, at any rate the higher ones, are rooted to the soil. This necessitates their dependence upon the substances available in the soil to which they are fixed and in the air surrounding them. And we know that only inorganic substances are found everywhere on the earth and in the air. As plants have to take these available substances in the form of liquids and gases, a large amount of space is obviously required for their absorption. So they have a branching habit both in their roots and shoots.

All plants are green in colour. The presence of this green colour enables the plants to build up organic materials. All the differences between plants and animals are due to this plant-power.

Animals have to use for food organic substances, which consist of special complex substances forming part of, or produced by other animals or plants. Therefore, in order to secure their food, animals should move about freely. And for free locomotion the body of an animal must be compact in form and arrangement of parts or organs.

If we only think of the essential features of these two processes, nutrition and reproduction, we perceive that there is no great gulf separating the animal from the plant. On the other hand, the similarities existing between the two great classes of living things are even more striking than are the obvious differences. As a matter of fact, we have some low organisms living in water and called Euglaena which move about rapidly in water and so these are called animals. They are unicellular organisms and each one contains within its

body a small body, green in colour. Similarly there are small plants, that are unicellular and green also running about quickly in water. After all, the differences seen consist in features mainly of secondary importance.

Between animals and plants there is also a characteristic difference with reference to energy, which is also due to the difference in their mode of feeding. Life, after all, consists in the expenditure of energy. All living organisms may be viewed as machines transforming energy. We know that animals consume organic food. This food has plenty of energy locked up in its molecules; and this potential energy is transformed into kinetic energy seen in the motion of the body and in the production of heat. Plants also are machines concerned with the transformation of energy. The presence of green colour, existing as green corpuscles in plants, enables them to obtain the energy available in sun's rays and build up organic substances. This is really transforming kinetic energy into potential energy.

Both animals and plants have to spend their energy for their life processes. In the case of animals the expenditure of energy is more rapid than in plants. Furthermore plants are able to make large quantities of organic material and, out of them, only a very small portion is utilised by them as the source of energy for all the work that they do. In other words, plants tend to accumulate organic material which may be used by plants or animals. On the other hand, animals feed, directly or indirectly, upon plants and their products. To put it briefly, animals are consumers and plants are builders.

It is not amiss to say that no animal can exist without plants, nor can we expect to have energy on the surface

of this earth without the intervention of plants. All the energy utilised in working the varied machinery in factories is traceable to coal. And coal is a plant product. The energy locked up in coal was stored up by plants ages ago. When coal is burnt energy is set free. In other words, energy locked up by plants ages ago, with the help of the sun's rays, is being now dissipated by burning the coal.

The peculiar power of the chloroplasts forms the starting point of the food supply of the world. In the absence of chloroplasts neither plant life nor animal life is possible. So, in a sense, we may say that the real source of energy for plants and animals is the sun.

Knowing as we do that animals are dependent on plants, directly or indirectly, for their food, they could not have come into being before plants. So plants must be considered to be older than animals. They are, therefore, the first and most original form of living beings and without them no life of any sort would be possible.

All living matter is manufactured by plants out of the materials found in the soil and in the air, under the iufluence of sunlight. We know that without living matter new living matter cannot be formed. One may, therefore, legitimately ask how the first plant came into existence. This cannot be answered with any certainty. We can only guess that in the early ages of the world the earliest living body came into being because the conditions favourable for its formation then existed. At the present time those conditions do not exist. It is highly probable that in former ages the matter was more plastic and that certain combinations of atoms were possible then, but not now. This spontaneous appearance of living matter must have occurred once at least.

But it is certain that "spontaneous generation" does not now take place. At any rate, at the present day, every living being whether plant or animal is the product of a living being, its parent or of two previous living beings, its father and mother.

The first formed or primitive forms of plants must of necessity be very simple plants. Such plants persist even now and they consist of small specks of jelly-like matter freely floating in water. They are green in colour. Therefore, they have the power of building up fresh living material when sunlight falls on them. As soon as each of these plants attains a certain size, it splits up into two or more similar parts. And all of them again continue to live and then behave exactly like the original plant from which they arose. This coming into being, of two or more organisms from a single one, is the simplest form of the process of reproduction. All higher forms of plants must have been descended from these primordial forms.

From the fact that living matter is manufactured only by plants, we should not conclude that living matter is something mysterious and peculiar and that they are not subject to the influences of the ordinary physical and chemical laws. Living matter is also influenced by physical conditions and is subjected to the influence of chemical laws just like dead matter. It is true that there are differences between the reactions occurring inside the living body and those taking place outside it. These differences are obviously due to the greater complexity of substances concerned in the living matter. For the present our methods are probably not sufficiently accurate and delicate enough to bring about the reactions outside successfully. Furthermore the frame work of living matter or of living things consists

of the peculiar state of aggregation of matter usually described as colloidal. Probably this colloidal character provides the conditions necessary for the chemical reactions. The materials constituting living matter are vast in their range and, therefore, it is impossible to analyse the results of experiments sufficiently well to refer them to their proper causes.

We have to study plants from different standpoints of view. For the sake of convenience these different views are considered separately each forming a section of botany. For example, we have to study the external features and the internal structure of the members or parts of plants. The former forms the section called **Morphology** and the latter constitutes **Histology**. The various life processes have also to be considered and this forms the section of **Physiology**. The multitude of individual plants, we know, are varied in form and structure. We compare plants with one another and group them into classes or divisions. This part of botany dealing with classification is called **Systematic botany** or **Taxonomy**.

Plants are usually divided into four main divisions as shown below :—

1. **Thallophyta**.—This is the lowest division of plants and comprises the lowest and simplest of plant-organisms. The plant body is either a single cell or an aggregation of similar cells without any differentiation. Though these, considered individually are small and inconspicuous, they are very numerous in species and genera. These include Algae, Fungi and Lichens.

2. **Bryophyta** or **Muscineae**.—These are the mosses and the liverworts. These plants do not show much differentiation, although in some higher forms some slight differentiation into stem and leaf may be seen

In all situations where there is sufficient moisture mosses and liverworts flourish very well.

3. **Pteridophyta.**—Ferns, clubmosses, horsetails and selaginellas constitute this division. They resemble the spermatophytes in showing differentiation into root, stem and leaf in the plant body or cormus and also in internal structure. Propagation is not effected by **seeds,** but by special unicellular bodies called **spores.**

4. **Spematophyta.**—They form the chief constituent of the flora of the land and are the highest type of plant life. These are highly organised plants with a very high degree of differentiation in their parts. Propagation takes place by means of **seeds** only. This group is further divided into the two sub-divisions, **Gymnosperms** (plants producing naked seeds) and **Angiosperms** *(plants producing seeds enclosed in seed cases).*

The first three groups are often called **Cryptogams** and the fourth being called **Phanerogams** or flowering plants. Occasionally the term **Cormophyta** is used and it includes Pteridophytes and Spermatophytes.

CHAPTER II

THE PLANT BODY

IF we examine some of our familiar flowering plants, w find that their bodies are made up of several distinct parts. The plant body or the **cormus** consists of the parts, root, stem, leaf, flower, fruit and seed. From a close study of a few plants it becomes obvious that the cormus of all Spermatophytes and Pteridophytes consists of these primary parts, whatever may be the size and shape of the plant. These parts have definite functions to perform.

Any common plant may be chosen to study its parts. The weed *Cleome viscosa*, growing in open waste places, will very well serve as a type. The green aerial portion of this plant usually grows erect and, as a matter of fact, the tendency of the shoot is always to grow upwards towards sunlight. The shoot consists of branches, all more or less alike in structure. Each branch consists of a central axis, the leaves and buds or small branches arising from it. The main stem which is in continuation of the tap-root goes straight upwards

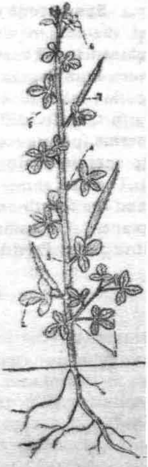

Fig. 1.—A full plan of *Cleome viscosa* 1, leaf; 2, leaflet; 3 node; 4, axil; 5, in ternode; 6, flower 7, fruit.

whilst the branches grow obliquely. On the branches besides leaves, flowers and fruits also make their appearance, although leaves precede them in point of time. In the stem leaves arise from definite places called **nodes**, and the part of the stem lying between any wo successive nodes is named an **internode**. The nternodes of a stem are not all of the same length, but they get gradually shorter and shorter towards the apex of the stem where the leaves get crowded. At every node a bud arises from the angle or the **axil** formed by the leaf with the stem. All buds develop nto branches and every branch repeats the character of the stem on which it arises. In all flowering plants buds or branches arise only from the leaf axils.

The most conspicuous feature of a plant is the presence of leaves and the whole mass of leaves of a plant is known as its foliage. As a rule the leaves precede the lowers and fruits in the life of a plant. Leaves are borne singly by the stem at every node and each leaf has a leaf-stalk or **petiole**, which bears three to five small green pieces called **leaflets**, all separate so that one piece may be removed without injury to others. In he leaf of this plant we see a long petiole having a blade which is cut up into distinct segments or leaflets and hence this is a **compound** leaf. Leaflets cannot be mistaken for leaves, because buds always arise from the axils of leaves, and never from the axils of eaflets.

On a branch the leaves at the lower portion have onger petioles and the length of the leaf stalk goes on decreasing gradually towards its apex. Further, the eaves are so disposed all around the stem as to enable all the leaves to obtain sunlight, and thus use up fully he available space.

On the branches of this plant, besides foliage leaves, we find bright yellow flowers coming out, one after another from the axils of leaves just like branches. Each flower has its own stalk to the free end of which the parts of the flower are attached. This stalk is called the **pedicel**, and its free end bearing the parts of the flower, one after the other in close succession, is termed the **receptacle** or **torus**.

On examining a flower bud or an open flower we see in its centre a very young undeveloped fruit, and this is termed the **pistil**. It consists of three parts, the cylindrical dilated portion or the **ovary**, a knob at the top or the **stigma** and the short column connecting the stigma and the ovary called the **style**. Within the ovary there are small white bodies, attached to the wall of the ovary or **pericarp**, and destined to become seeds. These bodies are called **ovules**. About ten to twenty fine thread-like structures with small knob-like bodies at their tips arise from the base of the pistil and are disposed around it.

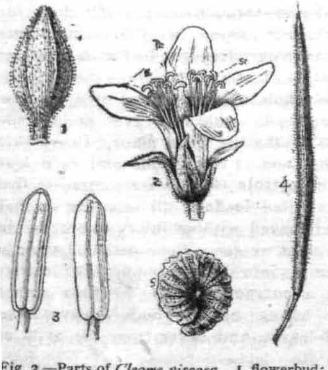

Fig. 2.—Parts of *Cleome viscosa*. 1, flowerbud; 2, open flower; 3, stamens; 4, fruit; 5, seed.

These are the **stamens**. The knob-like bodies at the ends of these threads are called **anthers**, and within the anther we find the yellow dust termed **pollen** consisting of small **pollen grains**. The most conspicuous ring of yellow leaves seen in the flower, next to the stamens, is the **corolla** and the members of this whorl are **petals**. Between and below the four yellow petals there are four narrow green structures, and these are the **sepals**, and the whorl of sepals is known as the **calyx**.

The fruit of *Cleome viscosa* is simple in its structure. It is cylindrical consisting of a wall or pericarp enclosing a single cavity. The seeds are attached to the pericarp in three or four lines. The seeds of *Cleome viscosa* are dark in colour, discoid and irregularly furrowed all over.

As in every other flowering plant, in this plant also, the lower portion of its body lies buried in the soil. When we pull the plant from the ground we find that we have to exert a little. From this we have to infer that the underground part of the plant, usually called the **root-system** helps in fixing the plant to the soil and prevent its being dragged out by the wind. If we dig out well-grown plants, with as little injury as possible to the roots, we learn that the buried portion of the plant or its root-system consists of a **main** or **tap-root** going vertically downwards and several lateral or **secondary** roots. The root-system of a plant is devoid of the green colour and all the parts are alike, only some are thick and others thin. On the other hand, the aerial part or shoot of the plant is green and consists of dissimilar parts.

As our next example for observation and study, we may select the plant *Tribulus terrestris* which flourishes everywhere in dry, open places. The whole plant

is softly hairy with all the branches of the shoot-syste lying prostrate on t ground. Its root-syste does not differ material from that of *Cleome viscos* but the tap-root is longe

Fig. 3—A branch of *Tribulus terrestris*. 1, node ; 2, internode ; 3, sitpule ; 4, leaf ; 5, leaflet.

The branches growing i all directions in a pros rate manner bear leave in abundance, and every node, there are tw leaves, one opposite th other. Generally one these at the node is smal er than the other, an occasionally it may als be absent. At every nod four triangular green pie ces occur close to the bas of the leaves as outgrow ths and these are the **stipules**. The petiole is generall short and the blade consists of several small leaflets, dis posed on both the sides of the midrib of the leaf. S this is a compound leaf.

Flowers arise singly from the axils of leaves an every flower has the same four parts found in the flowe of *Cleome viscosa*. In the *Tribulus* flower there are fiv green narrow sepals, soft and hairy outside, forming th outer most whorl of the flower. Between and above the sepals we find five yellow leaves somewhat wedge-shaped in form, and these are the **petals** constituting th **corolla**. Next to the petals inside, we find five shor stamens alternating with the petals, and five longe stamens alternating with the short stamens. In the

ntre of the flower lies the **pistil** and in the pistil e **ovary** and the **stigma** are well marked, although the style is almost absent. The ovary has five cavities and in each cavity lies a row of **ovules**.

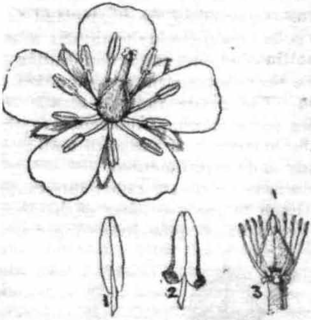

Fig. 4.—Flowers and its parts of *Tribulus terrestris*. The figure above is full flower. 1, and 2, stamens; 3, stamens and the pistil.

In flowers, at the time of their opening and when they are fully opened, we find all the four parts above described, but if we *examine them* later at different times, we do not find all the parts. In some we may ind all the parts, but the sepals and petals may be in a aded condition and about to fall off. In others they may ave fallen, leaving *only* faded stamens and the pistil n the living condition. In all the flowers and at different imes the pistil is generally present. This part, instead of remaining small, *grows* and, therefore, its *size* varies according to the stage of development. From this it is lear that certain parts only are directly concerned in the production of seeds, and these must be considered as the most necessary, and hence the **essential** parts of a flower. The pistil is undoubtedly one of the essential organs, because it contains the young seeds. As no seeds can be *formed without the help of the stamens*

they also constitute an essential part. The pollen grain formed in the anthers of the stamens seem to influence in some way the formation of the seeds. For this the pollen grains must be deposited on the stigma and this transference of the pollen grains from the anthers to the stigma is termed **pollination**, and the action leading to the formation of the seeds subsequent to pollination is called **fertilisation**. The petals and the sepals are only the enveloping parts affording protection to the two inner organs, the stamens and the pistil until they are mature and ready to do their functions.

The fruits of *Tribulus terrestris* are rather interesting in some respects. Each of the five lobes of this fruit bears at its back two pairs of spines, the upper pair

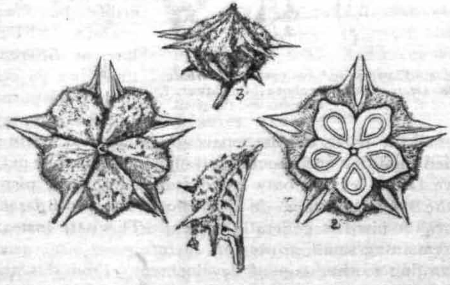

Fig. 5.—Fruit of *Tribulus terrestris* and its segments. 1, fruit; 2, fruit cut across; 3, side view of fruit; 4, one segment.

being longer than the lower pair. The fruit breaks up into five segments when it is fully ripe. Inside each of these five segments of the fruit there are four to six thin

at, ovate seeds. The hard covering and the spines elp, not only in affording protection to the seeds but lso helps in its dispersal.

Every plant has a definite course in its life. A plant egins its life as an embryo enclosed in a seed in a ormant state, then it germinates and grows into a eedling. The seedling grows, puts forth the leaves and ranches, sends its roots into the soil where they branch oing in further and further, and becomes a mature lant. Later on flowers appear and they remain attractive and fresh for a while, and after doing their work they fade away. The stalk or the pedicel which bore the flower now supports the swelling fruit, within which seeds are ripening. When the fruits are mature they burst open and scatter the seeds, which are really so many young plants let loose to travel as best as they can and thrive as distinct individuals. All these events in the life of a flowering plant, occurring in regular sequence, constitutes its life-history.

The life period of a plant, or its generation may be short or long. If the generation lasts only one season the plant is called an **annual**, if of two seasons it is a **biennial**. When it lasts for three or more years, the plant is **perennial**. These are some plants, like some species of bamboo that live for many years but flowers only once and die soon after the seeds have fallen. These are called **multiennials**.

From the study of a few plants, we learn that plants have definite parts and that those parts are, more or less, similar in essential points in all plants. In every green plant, whatever its size, we see two distinct parts, namely, the **root-system** and the **shoot-system**. The root-system is usually uniform in character. It generally consists of a tap-root bearing several lateral roots.

Of course they differ in size according to the dev
ment of the plant as a whole.

The shoot-system possesses uniformity only
respect to the position and formation of branches
considerable differences are seen in other resp
The flowers show the largest amount of variation i
their parts.

Both the root-system and the shoot-system
mainly concerned in the work of **nutrition** of pl
whilst flowers are concerned with the process of **re
duction.**

CHAPTER III

STRUCTURE AND GERMINATION OF SEEDS

ALL plants begin their lives as seedlings, and seedlings arise from seeds when they germinate. In order to understand the process of germination of seeds, and to get an insight into the growth and further development of the seedling, it is necessary first to know the structure of seeds.

We may begin the study of the structure of seeds with those of *Dolichos Lablab.* These seeds are attached in the fruit to the ventral suture by means of short stalks. When they mature and dry, they get detached from the fruit. So in every seed a scar is seen, on one of the edges, at the end of the spongy white streak found on the seed. This scar is called the **hilum**. At the other end of the white streak, away from the hilum, a minute hole exists in the seed-coat. The presence of this hole, or the **micropyle**, can be inferred from the fact that water comes out of the hole when a soaked seed is pressed between the fingers

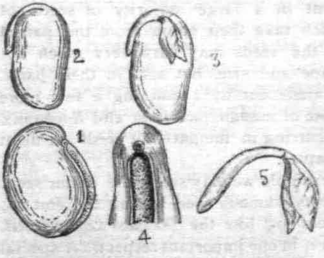

Fig. 6.—*Dolichos Lablab* seed and its parts. 1, seed; 2, embryo; 3, embryo with one cotyledon removed; 4, part of the seed-coat with micropyle; 5, primary axis.

A seed is essentially an embryo or an young plant

resulting from sexual reproduction. In a soaked seed, if the seed-coat is slipped off, the embryo comes into view. The embryo consists of a curved axis called the **primary axis** and two large flattened seed-leaves or **cotyledons**, which are attached to this axis, dividing it into an upper part or the **plumule** and the lower part or the **radicle**. The plumule lies compressed between the seed-leaves and this is the part that later on developes into the shoot-system of the plant. The radicle, or the lower portion of the primary axis, which later on gives rise to the whole of the root-system of the plant lies usually outside the cotyledons and on one side of them. The seed-coat within which the embryo lies, without being attached to it in any place, is somewhat thick and, as a matter of fact, it consists of two coats, an outer thick coat, the **testa** and a thinner inner one the **tegmen**.

The parts thus recognised in the seeds of *Dolichos Lablab* are present in a large majority of seeds of dicotyledons, which take their name from the paired seed-leaves. But the seeds may vary very much not only in their shape and size, but also in their parts. All this can be made out by examining a few more seeds, such as those of mango, *Cucurbita* and *Raphanus*. The variations occurring in the parts of seeds are dealt with in a later chapter.

As our second example we may select the castor seed. This is also a dicotyledonous seed having the embryo within the seed-coat just like the *Dolichos Lablab* seed, but differing from it in one important respect. A special additional tissue called **endosperm** is found within the castor seed, and this is not present in the *Dolichos* seed.

The castor seed is a large one with a hard, brittle, polished testa mottled all over, with streaks and blotches.

Within this testa lies the massive endosperm wrapped up by the tegmen. If this mass of oily endosperm, not represented in the seeds already considered, is split down in the middle in the plane in which the seed is flattened, then may be seen the embryo consisting of a short peg-like primary axis, with

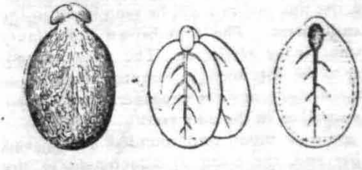

Fig. 7.—Castor seed and its parts. 1, full seed; 2, embryo; 3, endosperm.

which are connected two thin papery cotyledons. On a close examination it will be found that the cotyledons are immersed in the endosperm, in such a way that the whole of the outer surfaces of the seed-leaves are in intimate contact with it. Seeds, such as those of *Ricinus communis* or castor, in which the tissue endosperm is present, are called **endospermic** seeds. By contrast seeds, such as those of *Dolichos* and the like in which the endosperm does not occur, are called **non-endospermic** seeds.

We have next to consider the structure of the seeds with one cotyledon only, that is to say, of monocotyledonous plants. As examples for this class of plants, the seeds of Date and *Crinum* and the grains of maize or other cereal plants may be examined.

The date seed is very hard and, therefore, it is often called "date stone." It is somewhat cylindrical and pointed at both ends. On one side of it, about the middle, a small pit is present. This shows the position of

the embryo. A very shallow groove runs from this pit towards one end and on the other side of the seed there is a deep furrow extending from one end to the other. If the date seed is cut through the pit, both transversely and longitudinally, the tiny embryo will be seen lying in the hard horny endosperm. The thin brown outer layer covering the stone is the seed-coat. The *Crinum* seed, though similar to the date seed in essential respects, is larger, irregular in shape, and the endosperm is not hard. The embryo is small as in the date seed.

The maize grain is broad and rounded at one end whilst the other end, the point of attachment to the spike, is somewhat tapering. The two faces are flattened and on one face we see an oval depression due to the presence of the embryo. At the broad end, on the top of the face wherein lies the embryo, a small scar may be seen. This is the place of attachment of the stigma. The presence of two scars, one at the narrow end and the other at the broad end, clearly indicate that the grain is really a fruit enclosing a single seed. In the maize and, as a matter of fact, in the grains of all grasses, the so-called seeds are really fruits. In all these grains the seed-coat fuses with the pericarp, so that the two cannot be distinguished from one another.

To get an insight into the parts of the maize grain a soaked grain should be dissected and observed. In such a grain the outer skin may be removed easily and, then, the embryo is exposed on the side in which a depression is noticed. By careful manipulation the embryo can be detached from the grain, and then it will be seen to consist of a straight axis attached about its middle to the shield-like single cotyledon, called the **scutellum**. The bulky part left in the grain, after the removal of

the embryo, is the endosperm. The primary axis consists of the plumule and the radicle.

The position of the axis and the scutellum can be clearly made out in the transverse and longitudinal sections of the grain. The cotyledon folds over the primary axis and its outer surface lies in close contact with the endosperm and, therefore, acts as an absorbing organ.

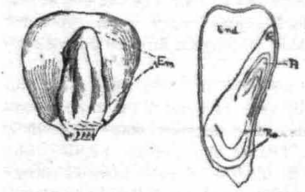

Fig. 8.—The maize grain and its longitudinal section. *Em*, embryo; *End*, endosperm; *Sc*, scutellum; *Pl*, plumule; *Ra*, radicle.

From the study of the structure of a few seeds it is obvious that the embryo or the young plant is the essential part in all seeds, and that this part is always protected by a firm seed-coat. The seeds of plants have to sojourn in the ground, and so they may very often be subjected to extremes of temperature or other unfavourable conditions. Unless the embryo is protected well from the evil effects of these conditions, it may perish. The seed-coat forms an efficient means to ward off the evil effects.

Every flowering plant makes supreme effort to propagate its kind by producing as many little plants or embryos as possible, packed compactly in seed-coats. Inasmuch as these little plants within the seeds get separated from the parent plant, each seed is really a separate individual. Mere production of seeds and their separation from the parent plant counts for nothing unless they are equipped with means to withstand

unfavourable conditions. Seeds in unripe fruits contain large quantities of water and as they mature they gradually lose water, and finally when they are fully mature and about to be detached from the parent plant, they become very dry. Dry seeds are better able to withstand the bad conditions and ward off the evil effects than living plants which contain much water. In a dry state seeds are capable of passing through a long resting stage.

In nature seeds are scattered at a time, when the conditions are not generally very favourable for their germination or start in life. The dormant stage of seeds is not without its use. During this period chemical and other changes, such as the loss of water already started and going on in mature seeds, are now completed. Unless these changes are completed, the young embryo within the seed runs the risk of being roused into activity, which, however, cannot be continued long on account of the want of favourable conditions, and consequently it perishes. The drying process, besides equipping the embryo with power to resist unfavourable conditions, renders the food-material stored in the seed stable.

From experience we know that seeds begin to show some activity, as soon as water gains access to them. The first sign of germination is of course the swelling of the seed by the absorption of water. It is interesting to note that in seeds also, just as in plants, the various parts are adapted to do certain definite functions. In the *Dolichos Lablab* seed, for example, there is a white spongy ridge on one end of which lies the micropyle. As soon as water comes in contact with the seed, a drop of water may get into the pit wherein lies the micropyle. This drop of water might obstruct the further

easy entrance of water into the seed. The white spongy ridge is very useful in this connexion. This ridge acts as a sponge in absorbing the water and allowing it to get into the seed through the micropyle freely. The tip of the radicle lies just close to the micropyle and the radicle is lodged in a small pocket inside the seed-coat. As water gradually accumulates in this pocket, the radicle is the first part of the embryo to receive water. The radicle takes in water and swells. Therefore the pressure on the seed-coat is most pronounced here. As the result of this pressure the seed-coat bursts here, somewhere close to the micropyle.

All these stages, beginning with the absorption anc swelling of the seed and ending with the emergence o the radicle through the slit formed in the seed-coat, con stitute the preliminary stage of germination. Soon afte its escape, the radicle grows rapidly downwards an very soon the root arises from its end. Later on latera roots arise from the central root and the young plar becomes firmly anchored in the soil. In the seedling is the roots that make their appearance first, and it mu obviously be so inasmuch as every plant has to be fixe in the soil, and this is an essential condition for the va majority of flowering plants. Furthermore, water whi is so essential for the growth of the seedling has to obtained from the soil and for this roots are necessary.

Whilst the roots are gradually developing from t lower end of the radicle, its upper portion lying bel the cotyledons, now called the **hypocotyl**, is slow growing and increasing in length. As the roots fixed well in the soil, this elongation of the hypoco has the effect of pulling out from the seed-coat a lifting the cotyledons up into the air. The hypoc comes out from the soil in the form of a loop, and

loop is the more mature region of the hypocotyl which pushes its way through the ground dragging after it the cotyledons, between which lies the plumule. The curvature straightens out, as soon as the cotyledons come out of the earth.

The early stages of germination take place within the soil in darkness and, therefore, the embryos cannot be expected to be able to manufacture starch and other food materials. So, for the growth of the young plant, food materials must be supplied. As a matter of fact, in *Dolichos Lablab* seedling, whose germination we have been describing, the early growth of the embryo takes place at the expense of reserve food-material stored up in its cotyledons. The gradual removal of the food-material from the cotyledons can be easily inferred from an observation of the seedlings at sucessive stages of development. In young seedlings the cotyledons are usually well filled and plumpy, in older ones, they are shrunken in appearance.

The behaviour of the radicle, so far as the formation of the roots are concerned, is exactly the same in all dicotyledonous seeds. But we notice differences in the manner of the escape of the plumule from the seed. In the case of *Dolichos* seeds, whose germination we have been considering so far, all the parts above the upper portion of the radicle or the hypocotyl are lifted up into the air, by the active growth and elongation of the hypocotyl. But there are seeds, such as those of mango, *Cicer* and Pea, in which, whilst the radicle is growing during germination, the stalks of the cotyledons and the lower portion of the plumule which is just above the cotyledons, called the **epicotyl** begin to grow. The cotyledons remain in the seed-coat and the roots are firmly fixed in the soil. Therefore, the elongation of

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the epicotyl results in the pulling out the plumule clear off the seed-coat. During the time the epicotyl is growing the greater portion of the plumule and its tip undergo but little alteration in size. The tip of the plumule remains in a curved condition and it is really the mature portion of the epicotyl that pushes its way through the ground. As soon as the plumule comes up to light above the ground, it straightens itself and leaves begin to form. The leaves formed in the plumule, while it is underground, are very small and scale-like.

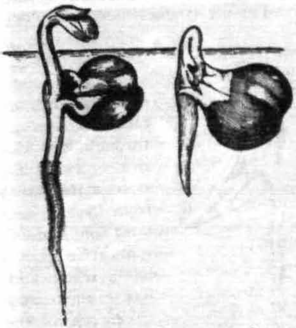

Fig. 9.—Germinating *Cicer* seeds. 1, advanced seedling; 2, young seedling.

From a consideration of the germination of seeds of *Dolichos Lablab* and those of *Cicer* or mango, we notice differences in the method of escape of the plumule from the seed. In *Cicer* and mango seeds the plumule escapes by the growth of the axis of the plumule or the epicotyl, and the cotyledons remain underground inside the seed-coat, whilst in the *Dolichos Lablab* seed the cotyledons with the plumule are lifted up into the air above the ground by the growth of the hypocotyl. The cotyledons are said to be **epigeal** if they come out of the seed-coat and rise up into the air, as in the seeds of

Dolichos Lablab, and **hypogeal** when they remain inside the seed-coat as in mango or *Cicer* seeds.

The germination of pumpkin seeds presents certain interesting features, although it does not differ very much from that of *Dolichos Lablab* seeds. As in other seeds, the radicle comes out through the narrow end and the root developes from its end and later on lateral roots arise from it in the usual manner. At the time of the escape of the radicle the slit is very small, but as soon as the root-system is well developed the hypocotyl and the cotyledons grow and exert pressure on the seed-coat, which is helpful in widening the slit. Further to facilitate the pushing up of the upper half of the seed-coat the lower half is pinned down firmly to the ground by the formation of a peg-like swelling at the base of the hypocotyl. (See Fig. 10). The cotyledons, though thick and small in the seed, grow larger after escaping from the seed-coat and behave like leaves.

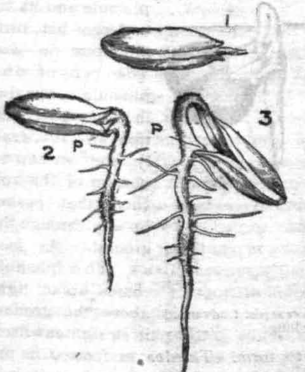

Fig. 10.—Germinating *Cucurbita* seeds. 1, seed just germinating; 2 & 3, seeds with advanced germination; P, peg-like structure holding the lower portion of seed-coat firmly.

The castor seed being an endospermic seed, its beha-

viour during germination differs from the seeds already described. The formation of the roots and the liberation of the embryo are exactly as in the seed of *Dolichos Lablab*. As there is a large quantity of endosperm, the cotyledons grow larger, absorb the reserve material and transmit it to the growing seedling. Until the endosperm is exhausted the cotyledons do not come out, and when it is used up they come out, become green and behave just like leaves.

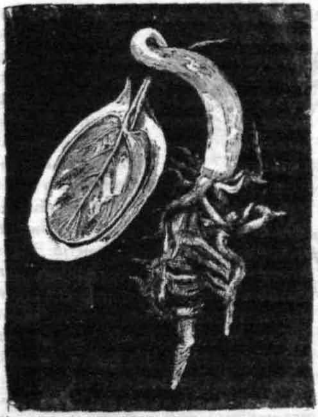

Fig. 11.—Castor seedling showing cotyledons and endosperm.

We have next to deal with the germination of monocotyledonous seeds such as those of date, *Crinum*, cocoanut and maize seeds.

The germination of date seed is very striking in certain respects. The tiny embryo, lodged in the small pit at about the middle of the date stone, begins its activity as soon as water is absorbed. The first sign of its activity is the emergence of the radicle. The stalk of the cotyledon sheathing the primary axis grows

and consequently the primary axis is pushed out rapidly. At the lower end of the primary axis roots arise and from the slit in the upper portion comes out a stiff pointed structure, the plumule which is made up of young leaves one folded with in the other. For the growth of these parts food material has to be supplied and it must be obtained from the endosperm. The cotyledon which lies embedded in the endosperm grows gradually larger and larger, as germination progresses, and its surface also increases. Simultaneously with this the endosperm gets softer and softer and the cotyledon, now having a large surface, absorbs the food material and transmits it to the seedling through its stalk.

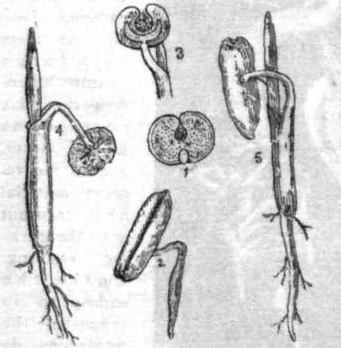

Fig. 12.—Germination of date seed. 1, seed cut across; 2, very young seedling; 3, seedling with endosperm cut across to show the cotyledon; 4, seedling and the cotyledon; 5, advanced seedling with seed attached.

The germination of *Crinum* seed is practically similar to that of date stone. The endosperm is not hard and the cotyledon is different in shape.

The cotyledon, though very small in the embryo in the resting stage, it increases considerably in size during

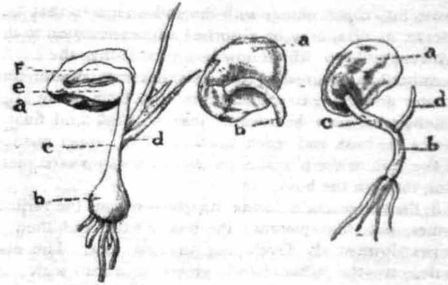

Fig. 13.—Germination of *Crinum* seed. a, endosperm; b, hypocotyl; c, stalk of cotyledon; d, plumule; e, endosperm cut through; f, cotyledon.

the germination of the seed both in *Crinum* and date. A notable example of the cotyledon assuming a very large size is afforded by the coconut. The embryo in the nut is very small and it lies embedded in the white oily endosperm, just below one of the three openings of the shell at one end. For germination the coconut is buried in the soil with its husk intact. If the husk is removed germination is not possible. During the earlier period of germination a portion of the cotyledon grows out through one of the openings in the shell and carries the whole of the primary axis out with it. The greater portion of the cotyledon lies within the seed inside the shell and it absorbs the endosperm, becomes larger and finally fills the cavity completely. The external surface of the enlarged cotyledon

Fig. 14.—Coconut seedling showing the cotyledon.

comes into close contact with the endosperm so that the reserve material may be absorbed and transmitted to the growing embryo, which now lies outside the shell. As germination progresses, the axis becomes stouter and stouter and elongates, and roots arise from it one after another and grow downwards into the husk and finally pierce the husk and reach the soil. The upper portion of the axis, or the plumule, grows and goes upward piercing through the husk.

In the maize grain during its germination the radicle comes out first piercing the root-sheath and then it grows downwards developing the first root. The plumule, on the other hand, grows upward with its sucecssion of ensheathing leaves. While still under-

Fig. 15.—Maize seedling. 1, plumule; 2, radicle; 3, sheath; 4, pericarp and seed-coat.

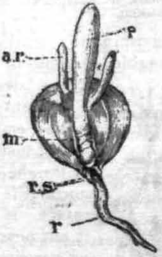

Fig. 16.—Maize seedling. *P*, plumule; *a.r.*, adventitious root; *r.s.*, root-sheath; *r.* radicle.

ground the tip of the plumule is pointed and firm, and so it is able to push itself up through the soil. The cotyledon is hypogeal. The first root grows downward

and very soon new roots arise from the axis and these also grow piercing the root-sheath and become as large as the first root. The roots in this case are called adventitious roots, because they all arise from the axis and not from the first root.

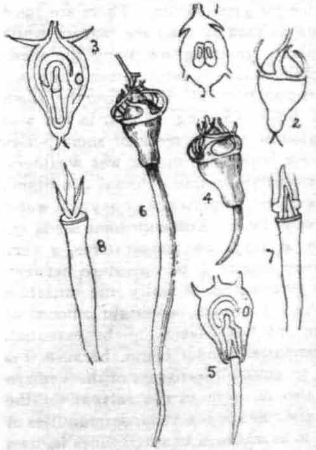

Fig. 17.—Mangrove seedlings in fruit. 1, ovary cut through; 2, fruit; 3, fruit cut through; 4, fruit in which germination has just commenced; 5, fruit and seedling cut through; 6, fruit with advanced seedling; 7 and 8, plumule.

As already stated every plant makes a supreme effort towards perpetuating its kind. And in most of the higher flowering plants perpetuation is the work of the seeds. In other words, the seed is an young plant thrown out by the parent plant, having been provided with food-material, so essential when it begins to grow, and also well protected. The need for protection of the embryo or young plant, which is after all the fundamental part in all seeds, is indeed very great inasmuch as the conditions outside may not always be favourable. When seeds leave their parents for their

travel they contain very little water, and in this dry state they are able to withstand great extremes of heat and cold.

Although a very large majority of seeds remain dormant and pass through a resting stage, it is not an essential condition for germination. There are some seeds that germinate as soon as they are mature while still on the parent plant. In mangrove plants the seeds pass through the earlier stages of germination while still on the parent plants and they fall down into the slush below as seedlings only. (See fig. 17.) It is not also unusual to see grains of ragi or seeds of some pulses germinating in the ear or the fruit during wet weather.

For successful germination certain external conditions are necessary. These are the presence of oxygen, water and a certain degree of heat. Although some seeds are known to germinate at very low temperatures, a very large number of them require a termperature between 15° to 25°C. Since germination is really the initiation and the continuation of growth, a certain amount of energy in the form of heat seems to be essential. Without water germination cannot begin, because it is necessary not only to stretch the tissues of the embryo inside, but it has also to serve as the solvent for the reserve food-materials. Seeds absorb large quantities of water, each taking in as much as hundred times its own weight; and this water stretches the tissues with a force equal to about two hundred pounds per square inch. The presence of oxygen is also essential. In its absence seeds fail to germinate even if the other two conditions exist. Oxygen seems to be necessary to sustain the respiration, which is the source of energy and to help in the formation of new diffusible compounds from the reserve material. It should not be forgotten that for

successful germination certain internal conditions must also be favourable. The parts of the embryo should be in a mature condition and the tissues must contain the special digestive ferments, so necessary in rendering the reserve material diffusible.

When the radicle peeps out, through the slit in the seed-coat, we may say that germination has begun, and this process is considered to have ended when the seedling has produced green leaves. During the period of germination several changes occur and some of them are visible, while others are not. The growth and increase in size of the various parts of the embryo and the appearance of new parts such as the formation of roots and leaves are visible, but the changes occurring in the reserve material cannot be seen. It is obvious that the reserve material is being largely utilised during the process of germination.

From a knowledge of the structure of seeds already considered, we learn that reserve material is stored up in all seeds and that in some seeds this substance is stored in the embryo itself, *i.e.* in the cotyledons, whilst in others just outside the embryo as endosperm. The reserve material is generally found in the form of starch in most seeds, although it occurs as oil in castor, gingelly and *Carthamus tinctorius* seeds and as hard cellulose in date seeds. Mixed up with the starch small quantities of proteins also are found. Whatever the

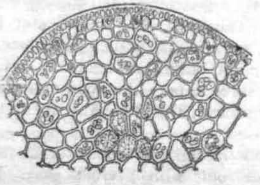

Fig. 18.—Starch grains in the cells of the cotyledons of *Dolichos Lablab*.

form of the reserve material, it is usually insoluble in water. Before this can be used it must be rendered soluble in water. In the cotyledons and in the endosperm certain special susbstances are formed in the cells, and as soon as water gains access to these parts, these special substances called **ferments** render the reserve material soluble in water. As the reserve stuff varies in its nature, there are different kinds of ferments acting on these different reserve materials. The ferment acting on starch is called **diastase**. These ferments can act only when water is present. Thus it is clear that water is necessary, not only to stretch the tissues and bring about the escape of the plant, but also to rouse the activity of the embryo and serve to take the food-material in a soluble form to various parts to enable them to grow.

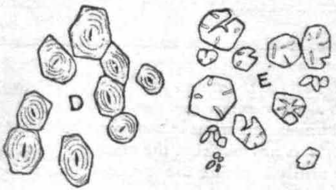

Fig. 19.—Starch grains of maize. D, entire starch grains in the endosperm; E, the same but corroded.

The presence of starch in the cotyledons or in the endosperm can be made out with perfect ease. If slices of cotyledon or endosperm be rubbed in water and the water allowed to stand, a fine white powder consisting of starch grains is precipitated. When a grain of maize or cholam is split longitudinally into two halves and the two halves are put in an aqueous solution of iodine, one portion becomes dark blue and another

portion remains yellowish brown. The dark portion is the endosperm mostly consisting of starch and the brownish part is the embryo without any starch in it. The common test for starch is iodine test. When starch comes into contact with a watery solution of iodine it becomes blue or purplish blue.

The cotyledons and the endosperm of seeds really consist of very small compartments of different sizes and shapes. Each of these compartments is called **a cell.** All the cells of the *cotyledon* and endosperm are filled with starch grains and these cannot pass from one cell into another, because the cells are closed on all sides. It is only when starch is rendered soluble and dissolved in water that it can pass through membranes of cells. As a matter of fact, all parts of plants are made up of cells. Cells, their nature, modifications and their arrangement into tissues &c. are dealt with in the section of Histology.

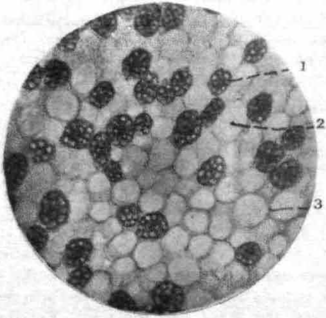

Fig. 20.—Cells in the cotyledon of *Dolichos Lablab*. 1, cell filled with starch; 2, empty-cell; 3, cell wall.

CHAPTER IV

ROOT

A PLANT grows attached to the soil and consequently it must have certain parts fixing it to the ground. The underground part of the plant is concerned with the fixation of the plant and it consists of many roots. The *whole of the roots of a plant is called its* **root-system.**

A plant begins its existence as an individual from its embryonic stage in the seed. In the embryo the plant-body or **cormus**, as it is sometimes called, consists of the primary axis and the cotyledons. This young plant grows at the expense of the reserve material in the seed, becomes fixed to the soil and very soon begins its career as an independent plant. If it is to thrive as an organism, it must get itself first established in the soil in such a way that it can make use of materials available in the soil, besides securing a firm anchorage. As a matter of fact, the cormus becomes differentiated into the fundamental organs, the shoot and the root. For the development of the shoot, the plant must first secure a foot-hold in the soil and for this the roots must develop first. From a study of the development and growth of the seedlings from the commencement of the germination of seeds, we know that the part which developes first is the root.

If we examine the root-system of a well developed seedling of *Dolichos Lablab* or *Ricinus communis*, we clearly see that it consists of a leading central root which grows vertically downwards and a number of lateral roots all arising from it and growing sideways

in different directions. The lateral roots are disposed around the tap-root in four distinct rows. *In most of the* dicotyledonous plants, the main root forms the downward continuation of the main stem and grows vertically down into the soil. From this tap-root spring lateral roots of the first order which penetrate the soil obliquely or horizontally. On the lateral roots of the first order those of the second order arise and this branching goes on in succession. As the result of this kind of development, the roots of successively higher orders are *thinner and they grow less strongly* than the roots from which they arise. The branches of the root-system get into the soil in all directions as uniformly as possible and, as branchings continue, do not leave even a cubic inch of soil unused. The *root-system* above described is typically racemose. A root-system, in which all the roots are directly or indirectly connected with the *main root, may be considered* to be a **normal** type of root-system.

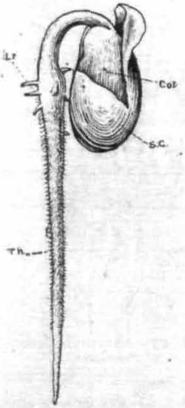

Fig. 21.—Seedling of *Dolichos Lablab.* Cot, cotyledon; l.r., lateral root; S.C., seed-coat; r.h., root-hairs.

In monocotyledonous plants a tap-root is usually wanting, because the first formed root becomes arrested. Numerous roots arise from the base of the stem and get into the soil vertically, obliquely or horizontally. All these roots bear lateral roots of successively higher

orders which penetrate the soil in all directions. In plants like cholam, maize and other cereal plants numerous roots, all more or less of the same size, grow from the nodes at the base of the stem. Such roots as

Fig. 22.—Adventitious roots of cholam.

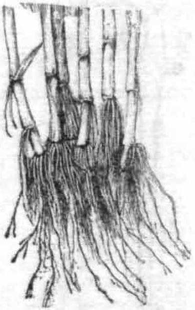

Fig. 23.—Adventitious roots of *Pennisetum*.

these are called **adventitious** roots. All grasses, plants having creeping or underground stems and cuttings produce adventitious roots.

If we examine the root of a young bean seedling, we can distinguish in it distinct parts. The free end of the root is naked and smooth externally, with its stiff and pointed end covered by a **root-cap** or **calyptra**. This part is the growing portion of the root. In most cases the presence of the root-cap cannot be made out with the naked eye, and without the use of a microscope. However, there are a few instances of roots in which the root-cap can be seen easily with the naked eye, as in

the aerial roots of *Pandanus* and banyan. Behind this portion comes the region of the root which is covered with root-hairs. The root-hair region lies in front of the older portions of the root.

The growing portion of the root really consists of two distinct regions. The extreme tip covered by the root-cap is one and the other region is the part of the root, lying between the root-tip and the root-hair region. The extreme tip is a very delicate part consisting of young actively dividing cells, and this is the actual growing point. During the elongation of the root-tip, the outer surface of the root-cap gradually wears away and becomes mucilaginous, so that the root-tip glides easily between the particles of the earth. As the root-cap wears away in front, new tissue is continually formed from the growing point behind, and thus the root-cap remains of almost constant thickness. The region of the growing part of the root, lying behind the root-tip, is the region where growth in length is most active.

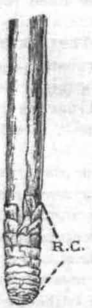

Fig. 24.—Root-tip of *Pandanus* R.C., root-cap.

The root-hair region, as already stated, occurs just above the elongating portion of the root. So long as the root is elongating, no root-hairs develop from its surface. But as soon as growth in length ceases in roots, root-hairs begin to develop from their surface. The advantage of this becomes clear if we remember that the function of these hairs is to absorb water from the soil. This function cannot be performed if the position of the root-hairs were continually altering with the growth of the root. Furthermore, under such

conditions the delicate root-hairs would be torn and become useless. The root-hairs grow between the small particles of the soil, with many of which they come into very close contact.

The chief functions of the roots are to attach the plant to the soil and to absorb the water and salts contained in the soil. The root-system would be able to absorb water, only if the plant is firmly fixed to the soil. Every part of the root-system is concerned in this work of anchoring the plant to the soil. The root-hairs adhere firmly to the soil particles, thus constituting so many hold-fasts. The tap-root grows straight down vertically and the lateral roots and their branches grow in all directions around the tap-root. These, therefore, support the plant.

The total length of all the roots of a plant would generally be very surprising. The root-system of even a cereal plant, such as paddy or wheat, for instance, will be several yards in length, when the roots are placed end to end. According to the investigations of certain botanists, the root-system of an oat-plant measured one hundred and fifty yards or so in length, although the spread of the root-system was only a cubic yard or two. The root-system of a pumpkin plant is said by Nobbe to have measured five kilometers (about 5000 yards.)

The root-systems of plants vary to a considerable extent and their nature and extent depend very largely upon the environment. The texture of the soil and the amount of moisture in it are the factors that influence the development of the root-system. Plants growing in a heavy compact soil cannot be expected to have a very extensive root-system, but in an open loose sandy soil it will be very much larger.

Roots, in order to meet the demands of a plant for

absorption and anchorage, must go deep enough and spread far enough laterally. A tree would naturally require a deeper and more extensive root-system than a herb. Roots are capable of growing to any length and there is no limitation for their growth. The development of the root-system and that of the shoot-system are intimately related to one another. For an increase in the root-system, a supply of organic materials is necessary, and this depends upon the leaves in the shoot. Again the increase in the shoot makes great demands on the water-supply from the roots, and this can only be met by the increase in the surface of the root-system. In other words, the root-system must develop more branches.

In all ordinary plants even including some trees the tendency of the root-system is to increase the extent laterally rather than downwards, because more of the requisite mineral matter is available nearer the surface of the soil than deeper down. Furthermore, the upper layers of the soil are better aerated than the deeper layers.

The roots of most cereals do not extend to more than four or five feet. Some have roots with greater lateral extension than others. In large trees such as the tamarind and the Rain tree the lateral roots may reach a length of 150 to 200 feet, but the depth to which they go is never so much. The lateral roots of these two trees grow along maintaining an average depth of not more than three or four feet. Roots of some trees, such as those of *Albizzia Lebbek* and *Acacia arabica*, go rather deep and some times their tap-roots go very deep, twenty feet or more.

In the case of certain trees growing in tropical forests the stems are rather high and very thick. Some of

these trees are supported at the base of the trunk b
very strong vertically placed buttress-roots. As ex

Fig. 25.—Buttress roots of *Bassia*.

amples we may mention the trees of the genera *Bassia*, *Vateria* and *Terminalia*.

The appearance of roots differs from those of aerial shoots. The green colour so characteristic of the aerial shoots and leaves is absent in the root-system. The shoot-system bears on the axis two kinds of lateral members, branches and leaves, whilst the root-system has only one kind of lateral appendage, the lateral roots. There are buds on the axis of the shoot, and none are found in roots. These buds are superficial outgrowths from the axis. But in the roots lateral roots do not arise from the outer portion and they spring from the deep-seated parts of the main root and push themselves out. The free ends of all roots are covered by root-caps.

It is true that roots do not normally bear buds, but when they are injured adventitious buds are formed on them. When the underground roots of *Ficus religiosa*, Margosa, Guava, *Clerodendron*, *Millingtonia*, *Odina wodier* and *Ixora coccinea* are severed, adventitious buds arise from the cut end of the root, which has got separated from the root which still maintains its connection with the parent plant. When the roots of guava are pruned by digging a trench around the base of the plant, numerous young guava plants spring up in the trench on the distant side.

So long as roots continue to perform their normal functions only, they are uniform and do not present any

Fig. 26.—Radish.

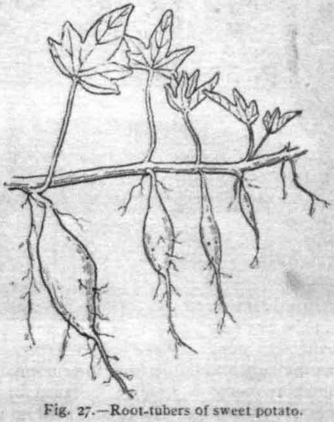

Fig. 27.—Root-tubers of sweet potato.

great modification. Roots are not without diversity in

form and size, but compared with modifications leaves and stems they are far less varied. The reas for this is that the conditions under which the ro grow are far more uniform. However much the variatio be upon the surface of the earth, the conditions for l in the soil are much the same all over the world. Wh roots have to perform functions other than absorpti and fixation, they present certain modifications. F example, in the case of plants such as radish, swe potato and certain species of orchids the roots, so lor

Fig. 28.—Banyan tree.

as they are young, perform their normal duties, but latei on they become swollen, because of the storage oi reserve materials. Roots modified in this manner may be called **root-tubers**.

Fig. 29.—Aerial roots of the banyan tree.

Roots of plants are usually situated in the soil. But here are also plants whose roots are exposed to the tmosphere. These are called **aerial roots.** In some lants these aerial roots remain always in the air, whilst a few others they remain so for a short time only and hen penetrate into the soil. Such aerial roots prop up he plants after entering the ground and this may be een in the cholam plant, the *Pandanus* and the anyan tree. After penetration into the soil these aerial oots behave just like ordinary underground roots.

The aerial roots of the banyan tree are well known and they are also of peculiar interest. These roots remain in the air for a fairly long time, but they grow in

length gradually and in the end penetrate the soi After getting into the soil these roots grow in thicknes and afford props to branches of the shoot-system. I the seedlin stage the ban yan plan grows occa sionally wit its roots atta ched to othe trees and, lon after, the root reach the soil We see ofte on palmyr trunks seed lings of banya growing epi phytically, for a time and, then the roots encir cle the sten and graduall grow down wards and ge into the soil.

Fig. 33.—Banyan tree growing on a palmyra trunk.

Adventitious roots spring from the nodes of such climbers as the pepper, the betel vines and *Pothos scandens*, and these are aerial and serve to attach the stem of these plants to supports.

There are a host of plants, mostly of the family Orchideae, in which the roots hang freely in the air and never penetrate the soil. The roots of the orchids *Vanda Roxburghii* and *Cleisostoma tenerum* hang freely

n the air and they never get into the soil. Plants whose roots thus hang freely in the air without getting into the soil are called **epiphytes**. The roots of epiphytes are specially adapted to obtain water and salts mostly from the air. In the aerial roots of *epiphytes* a few of the peripheral layers of the cortex become modified into a kind of spongy tissue, called the **velamen**.

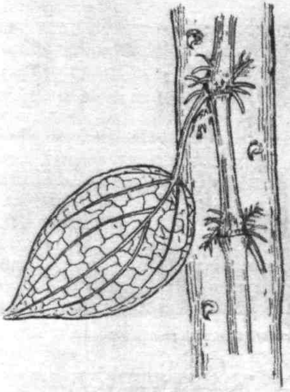

Fig. 31.—Aerial roots of pepper vine.

Plants growing in salt marshes have their roots in the mire, where the roots cannot obtain sufficient quantities of oxygen for respiration. So the roots of these plants send up into the air vertically upwards special roots, called **pneumatophores**, possessing a hole at the top to allow air to get into the root-system. The mangrove trees *Avicennia officinalis* and *Sonneratia acida* produce these pneumatophores in abundance. The aquatic plant *Jussieuea* aud the marsh plant *Sesbania aculeata* also posses peculiar roots serving as respiratory roots. The tips of these respiratory roots come up to the surface of water.

Roots are not at all green in colour, and yet this is not

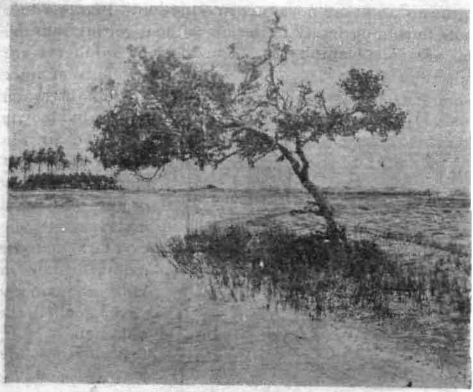

Fig. 32.—*Avicennia* tree with pneumatophores.

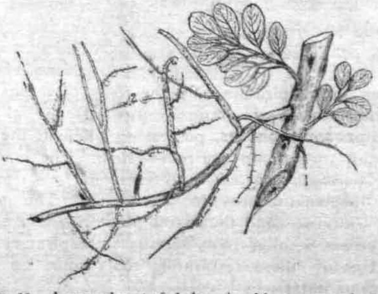

Fig. 33.—A normal root of *Avicennia* with pneumatophores springing from it.

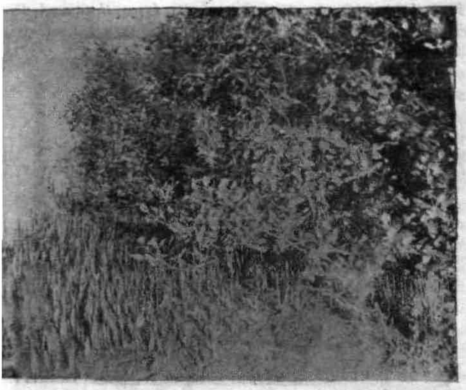

Fig. 34.—Pneumatophores of *Avicennia.*

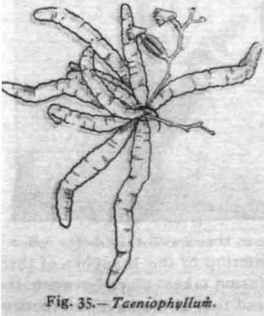

Fig. 35.—*Taeniophyllum.*

without an exception. In the very rare orchid *Taeniophyllum*, growing on the branches of trees in dense sholas on the Kodaikanal hills, the cormus of the plant consists of only the roots and the inflorescence. Consequently the roots are all green and do the photosynthetic work.

Roots of parasitic plants become modified.

The phanerogamic parasitic plants *Loranthus* and *Viscum* grow on the branches of other plants, sending their

Fig. 36.—*Loranthus* parasitic on branches of *Azadirachta indica.*

modified roots into the interior of the branches of their host plants. Complete fusion takes place between the xylem of the host plant and that of the modified roots of

e parasitic plant. The modified roots of the parasitic ants are called **haustoria**. Some parasitic plants such : *Striga*, *Balanophora*, *Orobanche* and *Santalum* attach themselves to the roots of their host plants, instead of the stems of the shoot.

Fig. 37.—A root parasite (*Balanophora*).

The root-systems of the plants of the family Leguminosae present certain special interesting features. We find pecial bodies of varying size and shape developing in he roots of these plants,and these bodies are called **bacterial nodules**. They are called so, because they are rought into existence by bacteria. These nodules, in irtue of the presence of bacteria, have the power of ixing in them the nitrogen of the atmosphere, and hus lead to an increase of nitrogen in the soil.

Lastly it must be noted that there are a few plants uch as *Utricularia*, *Ceratophyllum*, *Trichomanes* and *Psilotum* in which roots do not at all develop.

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CHAPTER V

THE SHOOT

THE purpose of germination in the case of every see is to enable the young embryo to develop into a seec ling, so that it may establish itself as a plant organisn with its root-system in the soil, and its shoot-syster exposed to air and light. On account of the apica growth taking place at both the ends of the primar axis, the root grows downward uniformly and persis tently into the soil and the shoot grows upward straigh into air and light. Therefore these regions are directl continuous one with another at the level of the soil. Th tendencies on the part of the root and the shoot, to g downward and upward respectively, is not accidenta The downward growth of the root is necessary for th well-being of the plant, because the root has work t do which it can do best in the soil. Similarly, the upwar growth of the shoot is equally essential considering tha the work that it has to perform is best done, only in th air and when exposed to sunlight.

As soon as the two regions of the plant body ar formed and well established in the soil, these regions though simple at first, begin to grow and become com plex. The root grows vertically downward due to th growth at its apex, and along with this elongation, ther arise on it lateral roots, which also in their turn posses apical growth. These lateral roots also behave exactl like the main root bearing them. Thus provision i made in every plant for mechanical support and als for the supply of water and salts from the soil. Jus

:e the root, the shoot also is endowed with the power continued apical growth and of forming an unlimited ccession of leaves. As soon as the shoot reaches the rface of the soil, either the cotyledons spread out in e form of thin green leaves, or the first leaves of the :d of the plumule quickly unfold and place their broad ırfaces more or less at right angles to the light from ıe sky. Leaves in the terminal bud of a seedling ıfold in succession one after the other in regular order ıd, therefore, the oldest are nearest the base and the ɔungest close to the apex, where the immature young aves are closely grouped so as to form a terminal bud. urther in the axils of leaves fresh buds may appear 'hich repeat the chief characters of the terminal bud. ach bud is capable of developing into a lateral branch milar to the main shoot, and so on. The increase ıking place in the number of roots or of branches of ıe shoot is usually on a very prolific scale. For the tilisation of water and salts absorbed by the root-ystem, the increased development of branches and :aves is necessary.

From what has been said above it is obvious that ıe root-system and shoot-system of plants are capable f indefinite growth. And, therefore, the growth and evelopment of these parts may be continued for many ears, until the plants attain very great size and high omplexity in branching. Although, theoretically con-idered, plants are thus of unlimited growth, in nature here are actual limits imposed. We cannot expect the ull development and growth of all the potential buds nd parts formed in a plant. This is a physical impos-ibility. Of the many axillary and terminal buds ppearing, some remain dormant, some may become ıodified and cease to exist, while others may be damaged

by fungus. Seasonal variations also may arrest the growth of parts. We have also to take into account the injury caused by animals or other accidental causes. Excessive flowering sometimes leads to the shortening of the life of a plant, as is the case with annuals.

The tendency of the shoot-system to become larger by the production of more branches and leaves enables it to avoid overshadowing by other plants. Any increase in the shoot-system of the cormus of a plant means a considerable amount of demand of water from the soil. And this demand must necessarily lead to the increase of surface and branching of the root-system. To enable the root-system to grow and increase in its surface, organic material must be supplied to it, and organic matter is manufactured only in the leaves. Thus we see that the development of the foliage and that of the root-system are intimately related one to the other.

The branching and general shape of the head of a tree is sometimes quite characteristic of the species, as in *Odina wodier*, *Ailanthus excelsa*, *Acacia planifrons*, tamarind tree and Rain tree.

The plumule is really a bud occupying the upper free end of the primary axis. We cannot make out its structure at the earlier stages of its development. But, as soon as it begins to grow, it becomes obvious that it is only a short stem hidden by a number of enfolding leaves. Gradually the stem elongates, the nodes become separated from one another, and the leaves also, which are crowded upon it at first, become separated. The shoot-system of a plant consists of a number of branches, and every one of them consists of an axis and the leaves and flowers borne by it. The axis or stem is divisible into nodes and internodes, and it terminates in a bud. All growing normal branches have buds at their

free ends. Some times the terminal bud is a resting bud and it is prominently seen in the twigs of mango, *Cinnamomum*, *Rhododendron* and Mahogany.

Besides the terminal bud there are also axillary buds in every branch. In a branch generally there will be as many axillary buds as there are leaves. We do not usually find buds in the axils of cotyledons, although they form the first pair of leaves. But we find buds developing in the axils of cotyledons in *Arachis hypogaea* and *Cicer arietinum*. When the plumule is injured in a seedling while still young, axillary buds develop in the axils of cotyledons, as in mango and *Canavalia* seeds.

Fig. 38.—Scaly buds of *Rhododendron*. 1, scaly bud; 2, scaly bud just opening; 3, scaly bud fully opened. 1, scale-leaves; 2, foliage leaves.

In the vast majority of plants, as a rule, only one bud developes in the axil of a leaf. There are, however, a few plants in which buds appear in addition to the single axillary bud. These buds may be collateral or side by side, as in some Malvaceae and Liliaceae, or serial or one above another as in *Lonicera*. Such buds are called **accessory buds**.

As already stated, buds normally grow in the axils of leaves in acropetal order. Occasionally, however, buds arise from other parts of the stem or from roots or even from leaves in any order. Such buds are called **adventitious buds**. Buds appear from the cut ends of roots and this has already been referred to (see page 43). When a leaf of *Bryophyllum* is placed in a

moist place or simply allowed to lie in the ground a large number of adventitious buds arise from the margin of this leaf. Shoots of *Begonia* and their leaves when injured, produce adventitious buds.

Fig. 39.—*Bryophyllum* leaves with adventitious buds.

A bud, terminal or axillary, is only an undeveloped compact young branch consisting of a short stem overlapped by crowded immature leaves. It is really the young incompletely developed end of a shoot. The axis of the bud terminates in a free end called the **growing point**, which is a mass of embryonic cells covered by the immature tender leaves. The leaves arising as protuberances from the surface of the growing point grow earlier and faster than the axis so that it may have protection. Though a branch has a large number of buds, all do not grow equally well. There are generally more buds than there is space for and so there will be a struggle for existence amongst them. Those buds that have more sunlight and room than the others grow best. The terminal buds and the axillary buds towards the top of the branch grow better and become larger, because they get more sunlight, air and room.

The result of growth may easily be studied on the twigs and branches of trees, especially in the twigs bearing scaly-buds. For example, on the mango or mahogany tree, each twig is terminated by a bud composed of external bud-scales, which enclose the closely folded foliage leaves awaiting expansion in the succeeding season. Below this terminal bud are seen leaves first and then leaf scars on the stem. Immediately above each leaf or leaf scar an axillary bud may exist which is capable of developing into a new branch; but frequently most of these axillary buds remain dormant. Lower down in the woody twig is seen a region marked transversely by many narrow scars, all lying close together. This zone may be taken as the lower limit of the growth of the preceding year, and the scars are those left by the fall of the bud-scales. All the portion of the twig lying above the zone of the narrow scars is the result of the growth of one season or a year. If we examine the branch lower down, we shall find several

Fig. 40.—A longitudinal section through the growing point of the stem of *Hippuris*.

zones of scars of bud-scales, the record of growth. Thus, passing from below upwards along the twig, we can make out its annual history, till we arrive finally at the terminal bud, which is providing for the development of the shoot for the next year.

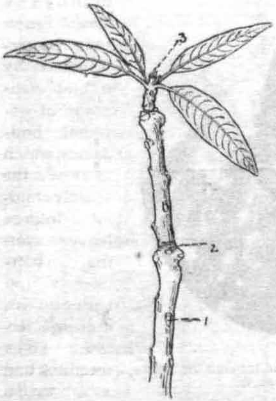


Fig. 41.—Twig of Mango. 1, leaf-scar; 2, scars of scale-leaves; 3, scaly-bud.

Although the primary shoot of a plant continues to grow and produce many branches, in some plants it may grow as a simple straight stem without any branches and remain so throughout its life. In the case of several palms such as the coconut, areca-nut, date and palmyra palms, the stem is single and no axillary branches are developed.

When a stem goes on elongating by the growth of its terminal bud for a long time, it is said to be a branch with indefinite growth. Sooner or later branches grow out from the lower axils also and these may be numerous, and all smaller than the main stem. This mode of branching of the stem is called **racemose**, and the branch whose elongation is due to the growth of the growing point of the terminal bud is said to be a **monopodial** branch.

In some plants very often the terminal bud, instead of

ontinuing the growth of the axis, ends in spines or owers. So the main axis ceases to elongate. Further ranching is carried on by the devalopment of axillary buds. This mode of branching is called **cymose**. In the plant *Carissa Carandas* the growing point after producing a few nodes and leaves ends in two spines, and the two axillary buds in the axils of the leaves immediately below the spines grow into branches. These also, after producing two or three pairs of leaves, end in spines and behave in the same manner. This mode of branching is termed **dichotomous** branching of cymose character.

Fig. 42.—Branch of *Carissa Carandas*.

A close examination of the flowering branch of a cotton plant and a bit of the stem of *Cissus quadrangularis* possessing tendrils at the nodes would reveal the fact, that the flowers and tendrils are opposite the leaves. In the cotton plant, as well as in the *Cissus* plant, the leaves are alternate and so in a branch bearing foliage leaves only there would be nothing opposite

the leaf. But in the flower bearing branch of the co plant the flower is opposite the leaf, because the g ing point of the main axis ends in a flower and the no growing point to continue the growth of the s axis. The axillary bud situated immediately below terminal growing point, now transformed into a flo grows and continues the axis by pushing aside flowers. So the internodes of the flower bearing br in the cotton p are not all der from the s growing p Such branche these are ca **sympodial** b ches and the b ching is cym On comparin branch of *Ci quadrangul* bearing ten with a branc the same p without ten the nature of tendril beco obvious. tendril is in the position of the main axis, and internode is found in the place of the axil bud. So the tendril is the terminal growing p modified, and the internode lying between the ten and the leaf is the axillary bud of the leaf opposite tendril. So the tendril bearing branches of *Cissus* also sympodial.

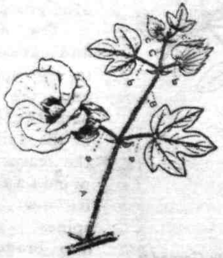


Fig. 43.—A flower bearing branch of the cotton plant. A, B, C, internodes; a, b, c, flowers; ȧ, ḃ, ċ, leaves.

Most plants grow erect because the upright position of he stem is after all the most advantageous one for the

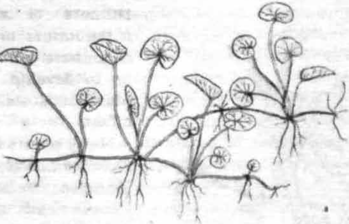


Fig. 44.—Creeping stems with adventitious roots of *Centella asiatica*.

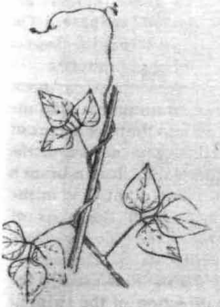


Fig. 45.—Twining stem of *Dolichos Lablab*.

plant. It is so because the stem has to bear leaves in such positions and at such distances apart, as to give them free access to sunlight and air. There are, however, plants possessing weak stems that do not maintain an erect posture. Such plants either grow on the suface of the soil creeping along, or they get support in other ways. The plants *Centella asiatica*, *Ipomoea reniformis* and *Lippia nodiflora* grow creeping along the ground. From the nodes of creeping branches adventitious roots arise, by which they get fixed to the soil. The axillary buds at

the nodes develop into erect foliage bearing branches The creeping branches may become independent plant if they get severed. Such branches as these are calle **runners** or **stolons** If the runner or stolo is a short one turnin up to develop into plant it is called a **offset.**

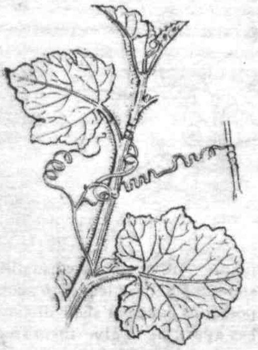


Fig. 46.—*Cucurbita* stem with tendrils.

Many plants such a *Dolichos Lablab*, *Clitore Ternatea*, *Teramnu labialis* and *Ipomoe sepiaria* have wea stems that twine them selves round a support All these plants ar termed **twiners**. Th support may be dead o living branches o plants growing near Certain plants like the cucumber, gourds, and pumpkin plants climb by means of special structures called **tendrils**. The nature of the tendril varies with the kind of the plant. It is a branch in *Cucumis* and *Cucurbita*; in the pea plant it is in the position of a leaflet; it may arise from the apex of a leaf as in *Gloriosa superba*; the flower stalk sometimes developes into a tendril as in *Cardiospermum Halicacabum*. In twining plants it is usually the stem that twines round, and the direction of the twining may be clockwise or anti-clockwise. There are a few instances in which the petiole twines round, as in *Clematis* and *Solanum seaforthianum*. The tendrils, as

soon as they secure attachment at their tips, coil into two spirals and the point of reversal is also clearly seen (see fig. 46.)

The axillary branches often remain short and pointed at their tips instead of growing into ordinary leafy branches. Branches of this kind are called **spines** or **thorns**. Occasionally these spines bear leaves and may develop into leafy branches under exceptionally favorable conditions and especially under cultivation. Examples of spines occur in plants of the genera *Citrus, Gymnosporia*, and in the species *Scolopia crenata, Phyllochlamys spinosa* and *Commiphora Berryi*.

The spines in *Citrus* plants are generally quite naked and green. In *Commiphora Berryi* the spines become

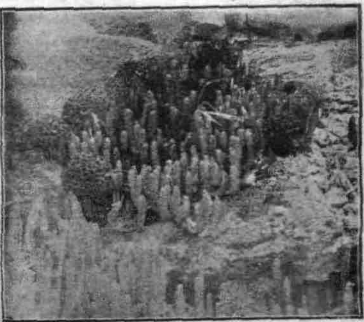


Fig. 47.—*Boucerosia* (cladodes).

numerous and prominent, and the leaves become fewer and scanty when growing in very dry situations. There

are many plants growing in dry situations in which the shoot-system consists of stems only without any leaves. For example, in *Bouccrosia, Opuntia,* and *Euphorbia antiquorum* leaves are not developed and the stems become fleshy and green. Such modified stems as these are termed **cladodes** or **cladophylla**. The cylindrical green structures so conspicuous in *Casuarina* are also cladodes.

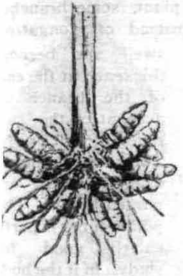
Although the majority of plants have aerial stems there are some plants in which some or all of the stems live and grow under the ground. The species of plants *Cynodon dactylon, Curcuma longa, Musa paradisica,* and *Allium Cepa* are familiar examples. The weeds *Convolvulus arvensis, Cyperus rotundus, C. bulbosus* and *Aristolochia bracteata* have perennial subterranean stems from which aerial branches arise year after year. It is on account of these under-ground branches that these plants persist as weeds.

When stems grow underground they are often mistaken for roots, because these are not easy to recognise as stems. Like aerial stems, the underground stems show division into nodes and internodes. At the nodes instead of green leaves, scales are found and in the axils of these scales axillary buds arise.

As underground stems differ from one another, some of the principal forms have for convenience been given special names. In some plants the underground branches do not materially differ from the ordinary aerial branches except in the loss of green colour and foliage leaves. For instance the underground branches in *Cynodon dactylon* are pale in colour and at the nodes whitish scales are found instead of leaves.

The underground stems of *Curcuma longa,Canna indica, Acorus calamus* and *Pteris aquilina* grow more or less horizontally giving off leafy shoots above and root

elow. The elongated forms of underground stems like ese are called **root-stocks** or **rhizomes**. The stems those mentioned above become much thickened on account of the storage of food-material. In some plants like *Panicum repens* and *Cyperus rotundus* the rhizomes are partly thin and get thickened partly here and there. In rhizomes the nodes, internodes and the axillary buds are clearly seen. Generally rhizomes do best at a certain definite depth and if this depth is changed, they will go downward or upward until the average depth is obtained. Rhizomes ordinarily grow orizontally, maintaining their average level in the soil, ecause greater depth is sure to interfere with the evelopment of aerial shoots, while extreme shallowness ould mean less protection.



ig. 48—*Rhizomes* of *Curcuma longa.*

Rhizomes branch freely. In some plants, as in *Curcua longa* and ginger, the whole of the shoot system may onsist entirely of underground stems, producing leafy erial branches, or only leaves may emerge as in the case f ferns. The rhizome may grow in length the apical ud persisting and axillary buds growing out into aerial ranches, or the apical bud may grow out as an aerial ranch, the growth of the rhizome in length being ontinued by lateral buds as in *Canna*. The former is of he monopodial type and the latter is sympodial. Plants ossessing rhizomes are best adapted for invading and aking hold of the soil already occupied by other

plants, because the rhizomes creep through the soil and occupy the places where seeds have absolutely no chance to spread.

Sometimes, as in the potato plant, some branches grow underground and these instead of elongating swell and become thickened at the end of the branch on account of the storage of starch. Thickened branches of this sort are termed **tubers**. The potato tuber is particularly good for study. In it the buds are clearly seen as "eyes" and these are found in the axils of little scales which represent leaves. The rounded bodies found in connexion with the slender rhizomes of *Cyperus rotundus* are of the nature of tubers. Often underground branches grow upwards develop aerial shoots and roots, as in the Rose plant. Such branches are called **suckers**.

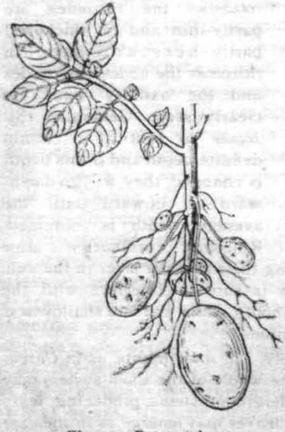


Fig. 49.—Potato tubers

There are a few plants in which the shoots are not developed, but much abbreviated. These consist of only disk-like stems with a covering of scale-leaves mostly fleshy, as in the familiar plants of Onion, *Crinum*, *Scilla*

nd *Urginea*. The scales of onion are fleshy owing to orage of food in them instead of in the stem. If we ut an onion longitudinally, we find a disk-like structure bearing roots below and a number of sheathing fleshy scale-leaves and buds above. Modified shoots such as the onion are called **bulbs**. The sedge *Cyperus bulbosus* bears small underground bulbs.

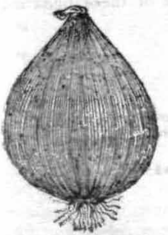


Fig. 50.—Onion bulb.

The inner leaves of a bulb are either fleshy scales as in onion, or they are merely the sheathing leaf bases of ordinary foliage leaves, as in *Crinum*. The bulb in *Polyanthes tuberosa* is generally ike that of *Crinum* or onion, but the xis becomes a large mass instead of emaining small and the sheathing eaf bases become very few. Exter- ally it is like a bulb and so such ones re sometimes called "solid bulbs". This is really an intermediate form of tem leading to what is usually lescribed as a **corm**.

The underground massive part of he plant *Amorphophallus* or *Synan- herias* is the main stem modified, and his is a good example of a **corm**. Though this is essentially like a tuber t differs from it in being a main stem nstead of a branch. The corm of *Amorphophallus* or *Synantherias* bears a large bud at its depressed apex.

Fig 51.—*Polianthes tuberosa.*

The apical bud pushes out the leaves one at a time. I addition to this bud a number of smaller ones ar found scattered all over the surface of the corm an also in the depressed part. Some of these buds ma

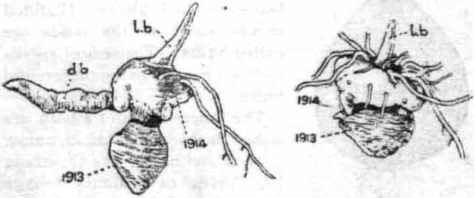


Fig. 52.—Corms of *Synantherias*.

develop into daughter corms. Adventitious roots ar also found on the surface of the corm. Sometimes w find corms of different periods of growth remaining attached to one another. For example, the corms in *Synantherias sylvatica* usually consist of two bodies, as seen in fig 52. The upper one represents the growth of one year and the lower that of the previous year. The underground structure found in *Colocasia antiquorum* in direct continuation with the developing bud is the corm; and this usually bears branches somewhat elongated and resembling rhizomes.

CHAPTER VI

THE LEAF

AVES are the most conspicuous lateral appendages of stems of the shoot-system. They are of paramount portance to a plant, as they are the organs concerned the production of organic material. Although a leaf an outgrowth of the stem like its branches, it differs ch from a stem, whereas a branch does not. Leaves always found in a plant and the most striking event a plant, even from the seedling stage, is the rapid duction of leaves. Ordinarily leaves do not persist the stem, but fall off after some time leaving leaf-rs on the stem. As old leaves fall off new leaves pear, so that there will be leaves always in most es, except in deciduous trees.

Besides the green foliage leaves, which alone are ant when we speak of leaves, there are other lateral growths which may be brought under the term leaf. e cotyledons, scale-leaves, bracts, sepals and petals : such outgrowths. The cotyledons are really the first ir of leaves of a seedling and we have already dealt h them in an earlier chapter. The scale-leaves are ially small, brown, membranous, without the green our. Judging from their position and arrangement the stem they are really reduced leaves. In most ses they are only leaf bases, petiole and lamina being sent. They occur on many underground stems and scaly buds (See Fig 38). Their function is chiefly tective. In some plants buds are protected by pules as in the banyan and the Peepul. Bracts also,

though connected with flowers, are really leaves. They vary very much. Sepals and petals are parts of the flower and hence they are floral leaves, and they will be considered later in connexion with the flower.

In a typical leaf we have three distinct parts, the basal portion of the leaf which connects the

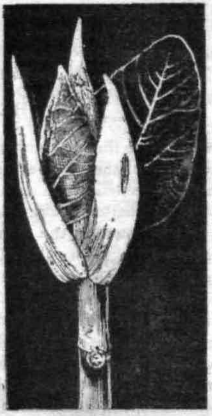


Fig. 53.
Terminal bud of a banyan.

Fig. 54.—Parts of a typical leaf.
1, node; 2, stipules; 3, petiole; 4, blade or lamina.

leaf with the stem, a stal
or the **petiole** and tl
blade or lamina, the e
panded portion. We d
not find all these thre
parts in all leaves. Fo
instance we do not fin
the stalk in the leaves
the plants *Lactuca runc
nata, Argemone mexican*
and *Sonchus asper*, a
though the lamina is pr
sent in all these plant

The leaf blade is present in almost all plants, and similarly the basal portion of the leaf must be expected to be present in the leaves of all plants. Young leaves forming a covering in buds do not possess stalks. The stalks develop only later, after the unfolding of the leaves.

In dicotyledonous plants the leaf base is usually short and small. It may be fleshy and thickened in some cases and then it is called a **pulvinus**. In the majority of monocotyledonous plants and in a few dicotyledonous plants of the family Umbelliferae the leaves have sheathing bases. For example, the leaves in *Musa*, ginger, turmeric and coriander plants possess sheathing bases. Leaves, however, in the majority of plants have only the blade and the petiole and not the sheath. A small minority have the blade only, without the petiole and the sheath. In grasses leaves have only blade and sheath, but no petiole.

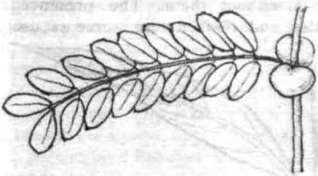


Fig. 55.—Leaf of *Cassia auriculata* with large semilunar stipules.

We often see two lateral outgrowths growing out from the leaf base one on each side, and these are called **stipules**. In the vast majority of plants the stipules are small, and in some they are not developed at all. They are very conspicuous and large in some plants such as the banyan and *Cassia auriculata*. In *Cassia auriculata* the stipules are large and semilunar. In all the species of *Polygonum* the stipules are tubular and

hence they are described as **ochraceous** stipules o **ochrea**. When leaves are young the stipules are cons picuous, but as the leaves mature, they fall off. In som plants the stipules become modified. For example, the are transformed into spines in *Acacia arabica* and othe species and in some species of *Smilax* they are prolonge into tendrils.

Leaves are said to be **stipulate**, if they have stipule and **exstipulate** if without them. The presence o absence of stipules and their nature serve as usefu

Fig. 56. Ochraceous stipule of *Polygonum*.

guides in the classification of plants. Thus, for example, the Leguminosae and Malvaceae have free lateral stipules and the Rubiaceae have interpetiolar stipules; ochraceous stipules characterise the Polygonaceae and the Cruciferae are without stipules.

The petiole is a cylindrical structure varying in length, and with its upper surface often grooved or flattened. The function of the petiole is to hold the lamina as advantageously as possible to suitable illumination. In some plants petioles are capable of movement up and down, especially when the base of the

f is thickened into a pulvinus. Petioles may have)endages on both the sides, as in orange leaf and in leaf of *Filicium decipiens.* Then the petiole is descri- l as a winged petiole. Occasionally the petioles me round supports as in *Clematis smilacifolia* and *'anum seaforthianum.*

The petioles often bear bladder-like swellings as in *apa bispinosa* and *Eichornea crassipes*, an introduced rsh weed now spread all over India. In some species *Acacia* the petiole developes into a flat structure y much resembling the leaf and the blade does not velop. Such petioles are called **phyllodes**. The yllodes assume a vertical direction and not horizontal e the lamina. The petioles with the leaf blades fall , but in *Quisqualis indica* the basal part of the leaf- lk persists and becomes woody in vigorously growing anches.

The leaf-blade or the lamina, which for convenience often designated shortly as a leaf, is always the sential part of a leaf because the formation as well as e transformation of organic matter takes place in it. ie lamina is usually thin flat and green. Ordinarily e leaf-blades maintain a horizontal position. The ide remains flat and stretched out, because it really nsists of a frame-work of firm veins which support an panse of thin, delicate tissues. In the vast majority leaves a prominent mid-rib runs up from the base of e blade to its apex, dividing the leaf into two equal mmetrical halves. From this mid-rib branch-ribs of ccessively smaller size pass towards the margins of e leaves. The branching of the veins are carried to ch an extent that the final small veins are hardly ible. Further these smaller, delicate, ultimate bran- es unite so as to form a fine net-work traversing the

thinner areas of the blade. In the leaves of dicotyle the venation is usually in the form of a delicate work and hence it is called **reticulate venation**. reticulate venation prevents the tearing of the mar

Fig. 57.—Reticulate venation in *Ficus* leaf.

of leaves, eve strong winds. some leaves, in *Antigonon* network at margin is r marked and sists of distin curved ve Such leaves dc get torn in t margins even the smallest tent. When culation is ab at the margin leaves, the margins usually get torn and the leaf b becomes torn into small pieces, as in the leaves of *M paradisiaca*. In the vast majority of monocotyledons veins run parallel to one another, though they are nected laterally by small transverse branches. venation is termed **parallel venation**.

Although the primary function of leaves is the s in all plants, they show much diversity in var features. In size they vary from a fraction of an i as in *Dentella repens* to several feet, as in *Musa*. S larly they present various shapes from linear to circ shapes. As regards duration, leaves are tempor lasting but one season in the majority of plants.

When leaves are young they are folded in the bu

ious ways. The folding may be considered with erence to the folding of each leaf on itself or folding h reference to one another. The former is termed **ptyxis** and the latter **vernation**. In many plants the two halves of the blade are folded along the midrib with their upper surfaces facing each other, as in *Anona* and *Thespesia populnea*. This kind of folding is described as **conduplicate**.

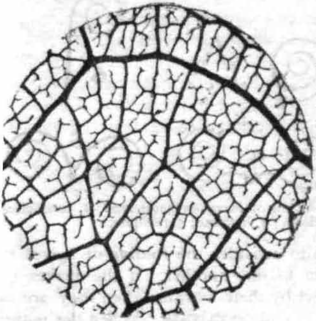


Fig. 58.—The net-work of veins in *Ficus* leaf.

'hen the leaf blade is rolled on itself from one margin the other, so that one margin being rolled towards the idrib remains inside and the other outside it, it is rmed **convolute**. The leaves in *Musa paradisiaca* and *anna indica* are convolute when young. In some leaves, s in those of *Nymphaea, Nelumbium, Ottelia, Viola, Commelina bengalensis* and *Terminalia Catappa*, both the nargins are rolled inwards towards the midrib so that the pper surface is inside, and this kind of folding is describ-d as **involute**. The folding is **revolute** when both the nargins are rolled towards the midrib so that the lower urface is inside. The leaves of *Nerium odorum* are evolute when young. The folding is termed **plicate** when the blade is folded upon itself several times as in

coconut and castor leaves. When the leaf is curl[ed] up from the apex towards the base as in a watch spri[ng] it is termed **circinnate**.

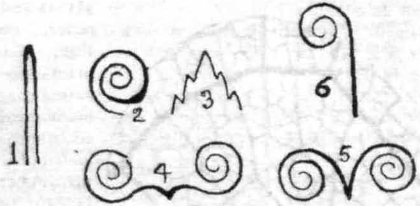


Fig. 59.—Ptyxis or folding of leaves on themselves. 1, conduplicate; 2, convolute; 3, plicate; 4, involute; 5, revolute.

We have also to consider the folding of leaves in a bud with respect to one another. If the leaves in a whorl merely meet by their margins, then they are said to be **valvate**. When the margins overlap one another, then the venation is **imbricate**. Where two conduplicate leaves enclose each other it is **equitant**. Venation will be fully dealt with in connexion with the flower.

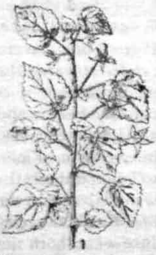


Fig. 60—Alternate leaves.

For the proper performance of their work the foliage leaves of a plant need sunlight. So the leaves of a plant must be so disposed on the stem as to get as much light as possible. Too much light, however, is injurious to leaves. Therefore, the adjustment of the position of leaves with reference to light is a delicate one. In most plants the

·es are horizontal in position, so that they may ·ive as many light rays as possible.

n examination of a leafy branch will show that ·es do not arise from it haphazard, but are definitely ·nged. The position of leaves with regard to light is ı that all the leaves get sufficient light without ding one another to any large extent. In other words, see that plants adopt every possible means of placing ·r leaves in such a position that they are least inter·d with by their neighbours, and their surface gets the greatest amount of exposure to light. The commonest methods of leaf arrangement or **phyllotaxy** are the **alternate** and the **opposite** plans.

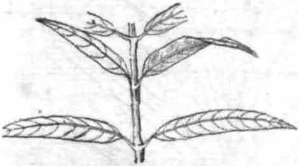


Fig. 61.—Opposite leaves.

ıen only one leaf is found at the node the phyllotaxy is ꟷ to be **alternate**. In this case the leaves will be found ·orm a spiral about the stem, as in *Hibiscus rosa-sinen-* *Abutilon*, *Anona*, *Tephrosia* and mango. When the ves spring from the nodes in pairs facing each other y are said to be **opposite**. If there are more than › leaves in a node they are said to be **verticillate** or ıorled. Leaves are opposite in *Morinda*, *Calotropis*, *nca* and Pomegranate. They are whorled in *Nerium* ꟷ *Clerodendron*. In stems with alternate leaves, the ves will be in vertical rows. Between two successive ves on the same vertical line, a number of leaves will found, but at different heights and different positions. r example, in the normally growing branches of *Thes-*

pesia populnea or *Abutilon indicum* any leaf chosen will be exactly above or below the sixth leaf and the five leaves spirally arranged round the stem. The spiral will consist of two complete turns round the stem, and the first leaf will be separated from the second by a space equal to two-fifths of the circumference, that is to say 140° apart. In a spiral

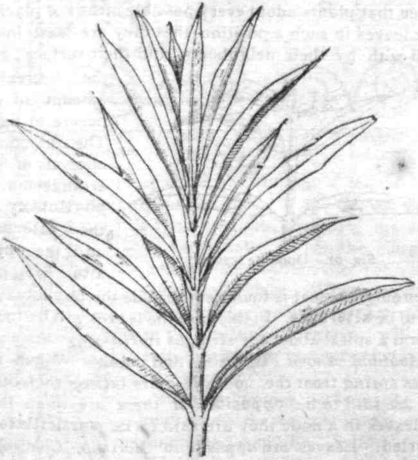


Fig. 62.—Verticillate leaves of *Nerium*.

of five leaves we get five vertical rows arranged round the stem at equal distances. These vertical rows or lines are called **orthostiches**. The simplest case of arrangement of leaves occurs in grasses. The successive leaves stand one half-way around the circumference of

the stem from those next above and below, so as to form two vertical rows bringing the third leaf above the first. The arrangement is called **distichous**. When the leaves are arranged in three orthostiches and the divergence of leaves is one-third the arrangement is termed **tristichous**. The arrangement already described as occurring in *Abutilon* and *Thespesia* is **pentastichous** and the divergence is two-fifths. Other higher divergences also occur. In some, as in *Carica papaya*, it is 3/8 and it may be 5/13 as in *Spondias mangifera*. The fractions used to designate the phyllotaxy denote the divergence as well as the number of leaves and cycles. For example, ½ denotes one cycle, or complete spiral and two leaves and the divergence is 180°; 2/5 denotes a divergence of 140°, two spirals and five leaves. In other words, in these fractions, the numerator denotes the number of spirals and the denominator the leaves or orthostiches.

When the leaves are opposite the successive pairs will be at right angles to one another. In other words, the leaves at any one node will be across the leaves of the nodes above and below it. This arrangement of leaves is termed **decussate**. If the leaves are in a whorl, the leaves of the alternate nodes are exactly one above the other, and the leaves of the successive nodes will be found on different vertical lines side by side.

Leaves manage to avoid shading one another not only by means of phyllotaxy, but also by other means. If we look at the leaves on the shoots of *Acalypha* or *Amarantus* from above, the leaves will be found arranged in rows round the stem in such a way as to utilise the space to the best advantage, without shading each other. The leaves below are not shaded by those above, because the petioles of the former are longer than those of the latter. Further, the size of the leaf blade also has some bearing

on the disposition of leaves round the stem. If the leaves at the nodes are broad, the number of leaves in the whorl will be less, but if the leaves are narrow more leaves spring from the node to form the whorl. Whatever the number of rows around the stem, all the leaves get their share of light, because the rows are not likely to shade one another. But in the same row, leaves above are likely to throw those below into shade.

Fig. 63.—Leaf mosaic of *Physalis minima.*

As a matter of fact this does not happen so as to interfere with one another. By the adaptation of the length of the blade shading is avoided.

In some cases the leaf surfaces present beautiful mosaics and rosettes. For example in many Solanaceous plants such as *Solanum nigrum* and *Physalis minima* the leaves are not at all uniform in size and so the leaves arrange themselves in mosaic fashion. The introduced

plant *Sempervivum* affords an excellent example for the mosaic arrangement of leaves.

Many plants of the family Compositae may be cited as examples for the rosette habit of the leaves. The leaves in *Lactuca runcinata* and those in some species of

Fig. 64.—Leaf mosaic of *Sempervivum*.

Blumea are mostly confined to the base of the plant. In other words, the leaves are radical. In all these plants the leaves are narrow at least in their lower portions and so they are disposed round the stem so as to form a rosette. It is easy to give more examples; for instance,

Trapa bispinosa, *Etytraria crenata* and *Elephantopus scaber*.

The same principle, namely, that the leaves should spread themselves so as to enable all the leaves to be illuminated and, at the same time, avoid shading one another is very well brought home by the heads of trees. For instance, the heads of trees such as those of banyan are generally found covered by leaves externally so as to form a frame work or covering with as few gaps as possible. To enable all the leaves to obtain sufficient light this is the best possible arrangement. If we look at the head of the same tree from inside and from near its trunk towards the branches, we find large spaces between boughs and twigs and no leaves are found distributed in these gaps.

Shape of leaves:—The shape of the lamina varies very much, but it can be referred to one or other of the shapes described below. A leaf is said to be **linear**, when the blade is very narrow, with the sides almost parallel, as in most grasses. It is termed **lanceolate** or **lance-shaped**, if the blade of the leaf is somewhat broad at about the base and tapers towards the apex, as in *Polygonum*, *Polyalthia longifolia* and *Nerium*. A leaf is **elliptic**, if broad at the middle and tapers towards the apex and the base, as in *Ficus elastica*.

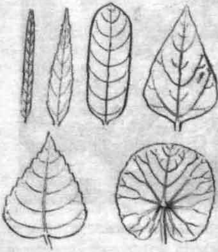


Fig. 65.—Shapes of leaves. 1, Linear; 2, lanceolate; 3, oblong; 4, ovate; 5, cordate; 6, rotund.

When the margins of a leaf are almost straight and

the blade uniformly broad, as in Guava, banyan and *Calotropis*, it is **oblong**. Leaves which are broad and round at the base and also tapering to a point at the apex, as in *Hibiscus rosa-sinensis* and *Solanum nigrum*, are described as **ovate**. When the blade is broader at the apex and narrowed towards the base, as in the leaflets of *Cassia obovata*, it is **obovate**. If the lamina is hollowed out at the base and pointed at the apex so as to be roughly like the heart-spot on a playing card, as in the leaves of *Thespesia populnea* and *Aristolochia bracteata*, the leaf is described as **cordate**. When the leaf is cordate, but with the apex rounded and somewhat broader than long, the outline is said to be **reniform** or kidney-shaped. The leaves of *Centella asiatica* are reniform. The shape of the leaf may be **round** or **rotund**, as in *Nymphaea* or *Nelumbium*. The leaf blade in some plants, as in some Aroideae, are like an arrow-head in its shape, and, therefore, they are called **sagittate**. The leaves of the

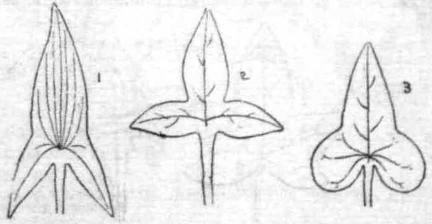


Fig. 66.—Shapes of leaves. 1, sagittate; 2, hastate; 3, auricled

plant *Sagittaria sagittaefolia* are sagittate. If the basal lobes of a blade are straight and at right angles to the blade, the leaf is then **hastate**. If the basal lobes of a

blade are rounded and prominent, the leaf is said to be **auricled**.

Margin of leaves:—When the margin of a leaf is

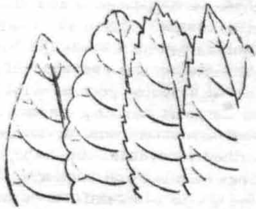


Fig. 67.—Leaf margins. 1, entire; 2, crenate; 3, serrate; 4, dentate.

quite even without any cuts or indentations, as in banyan leaf, it is said to be **entire**. It is **repand** when it is entire and wavy, as in *Polyalthia longifolia*. When the margin is cut up into distinct and prominent teeth, as in

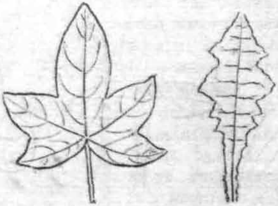


Fig. 68.—Lobed leaves. 1, Palmately lobed; 2, pinnately lobed.

Hibiscus rosa-sinensis, it is **dentate**; it is serrate, if the teeth are small and directed upwards as in *Acalypha indica*. Sometimes the margin possesses teeth that are

rounded as in *Bryophyllum calycinum*, *Centella asiatica* and *Stachytarpheta indica* then the margin is **crenate.**

Leaves in certain plants have deep indentations in their margins. For instance, the cotton-leaf, leaf of *Hibiscus ficulneus* and castor leaf, are such ones and these are said to be **lobed**. If the cuts are deeper as in *Lactuca*, then the leaf is described as **cleft.** When the indentations reach almost the base of the leaf it is **partite.** *Jatropha multifida* has such leaves. The lobes in a leaf may be found on both sides along the midrib, as in the

Fig. 69.—Compound leaves. 1 and 2, palmately compound; 3 and 4, pinnately compound.

leaves of *Lactuca rnncinata*, and then the leaf is described as **pinnately** lobed. If the lobes are spread out like the fingers of a hand, as in *Hibiscus ficulneus* and *Jatropha* the leaf is said to be **palmately or digitately** lobed.

In the leaves of *Cassia auriculata*, *Cleome* and *Gynandropsis* the cuts are so deep that the blade is cut into distinct pieces, and a piece can be detached without in any way affecting the other pieces. Such leaves as these are called **compound** leaves, in contrast to leaves like those of *Thespesia* and *Hibiscus* which are termed **simple**. The distinct pieces of a compound leaf may be disposed

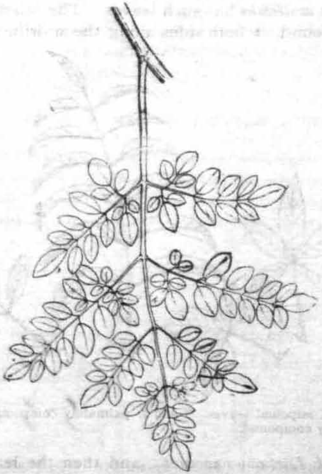


Fig. 70.—Decompound leaf.

pinnately as in *Cassia auriculata*, or **palmately** as in *Eriodendron* or *Gynandropsis*.

A leaf may be simply compound as in *Cassia auriculata* and end abruptly with an even number of leaflets, or it may end in a leaflet and have an odd number of leaflets. The former is described as **paripinnately** compound and the latter **imparipinnately** compound. Sometimes the leaf blade is divided more than once and then the leaf is said to be **bi-** or **tripinnately** compound or **decompound**.

Apex of leaves:—The apex of a leaf is described as **acuminate** if it tapers to a fine point gradually, as in the leaflets of *Dolichos Lablab* and leaves of *Ficus religiosa*. It is termed **acute** if it is merely pointed as in the apex of mango leaf. If the apex is rounded and blunt as in the banyan leaf it is **obtuse**. Sometimes the apex will be straight as though cut off and then it is said to be **truncate**; and if there is a notch it is said to be **retuse** if the notch is shallow, but if deep **emarginate**.

Like the stipule and the petiole the leaf-blade is also often modified. For instance, in the insectivorous plants *Drosera*, *Utricularia* and *Nepenthes* the leaves show distinct modifications. In *Drosera* the leaves are provided with glandular hairs secreting mucilage in such profusion as to imprison the insects, when the hairs come in contact with them. The leaves of *Utricularia* are modified into bladders with trap doors to catch insects. In the pitcher plant *Nepenthes* the leaves are prolonged at the apex into long processes ending in cups or pitchers. The pitchers contain a liquid. The insects are allured by these pitchers, so that they may fall into them and get digested by the water contained therein.

The bladders of *Utricularia*, the scale-leaves, petals, sepals, all these, look different from foliage leaves and they do different functions. But, when we consider their

position and development, they are all to be referred to the morphological part leaf. So members that are similar morphologically are said to be **homologous** members. The spines, the floral axis and the tendrils in *Passiflora* and *Cucurbita* are all homologous members. The tendrils of *Naravelia zeylanica, Smilax, Cissus quadrangularis* and *Pisum* are all alike from a functional point of view. In other words, these are **analogous** members. But morphologically viewed the tendrils of *Naravelia* and *Pisum* are really leaflets, and those of *Cissus* are stems. So these tendrils are only **analogous** and not **homologous.**

CHAPTER VII

THE INFLORESCENCE

THE shoot-system, during the greater part of a year, consists of foliage bearing branches constituting the vegetative region. Occasionally and at definite seasons in a year with periodic intervals, floral branches make their appearance. The flowers or flower clusters appearing in plants form the floral region. A flower, judging from its position, is morphologically a branch bearing floral leaves. In many plants flowers arise singly from the axils of ordinary green leaves, as in *Thespesia populnea*, and then the leaf subtending the flower does not differ from other foliage leaves. But, if flowers arise in regular succession one after the other from the axils of leaves, then the leaves become smaller and different in appearance also from the foliage leaves. Such reduced and modified leaves are termed **bracts**.

Flowers arising in large numbers on an axis or on several axes are collectively referred to as an **inflorescence**. If we carefully examine a number of inflorescences from different plants, we find that they are of various kinds. In some plants, as in *Crotalaria juncea*, the main axis may be simple and unbranched, bearing flowers throughout its length. The inflorescence may consist of several branches, secondary, tertiary and so on bearing flowers. The naked stalk of a solitary flower or the naked basal portion of the main axis of an inflorescence is called the **peduncle**, whilst the flower bearing portion of the axis is termed a **rachis**. The stalk of an individual flower by which it is attached to the axis is called a **pedicel**.

Owing to variations in the arrangement of flowers and also of branching of the axes in inflorescences we must necessarily have different kinds of inflorescence. For the sake of convenience distinct types are recognised and different names are given to them. The most common type of inflorescence is what is seen in *Crotalaria, Sesbania* and *Tephrosia.* In all these plants flowers are borne by an elongated axis in acropetal succession and all the flowers are stalked. An inflorescence of this kind is termed a **raceme**. Sometimes we find on the elongated axis, instead of pedicelled flowers, racemes and then the inflorescence becomes a **compound raceme**. In these plants the pedicels are more or less, of the same length. But in the inflorescences of *Gynandropsis pentaphylla* and *Cassia auriculata* the pedicels of the lower flowers are longer than those above and, therefore, all the flowers are at about the same level. This type of inflorescence is said to be a **corymb**.

Fig. 71.—A raceme.

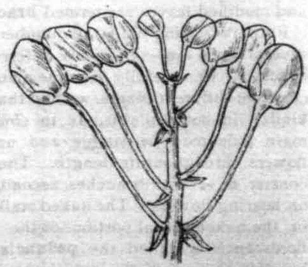


Fig. 72.—A corymb.

Other plants having corymbs are *Caesalpinia sepiaria*, *Cassia siamea* and *Ixora parviflora*.

Although flowers are pedicelled in many a plant, we find them in some plants without pedicels and sessile on the axis. For example, the flowers are sessile in the inflorescences of the plants *Amarantus*, *Digera*, *Achyranthes* and many other plants of the family Amarantaceae. This kind of inflorescence is known as a **spike**. It is not unusual to find in some plants, as for instance, *Colocasia*, *Amorphophallus* and other *Aroideae*, the axis of the spike becoming stout and fleshy, and associated with it we usually find a large sheath or bract. The axis is then called a **spadix** and the sheath a **spathe**. In some plants the spadix becomes branched very much and the spathe also grows larger and is firmer in structure. This is the case in most palms, and the inflorescence of coconut may be cited as an example. (See Fig. 75). Often the spike becomes a compound spike as in some grasses and Amaranths. The axis bears spikes instead of single flowers.

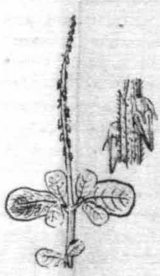


Fig. 73.—A spike.

We often see flowers springing from the top of the peduncle instead of from an elongated rachis. The pedicels of flowers are attached to the summit of the peduncle and not all along the axis in continuation of the peduncle. This type of inflorescence is called an **umbel**. If we have on the top of the peduncle umbels instead of pedicelled flowers, we describe it as a

compound umbel. The inflorescences in coriander, onion, *Calotropis* and *Daemia* are umbels. In *Heracleum* and *Bupleurum* the inflorescences are compound umbels.

Sometimes, as in the case of sunflower, the peduncle enlarges and becomes a flat disk at its summit, and on

Fig. 74.—*Amorphophallus* inflorescence.

the upper surface of this disk we find numerous sessile flowers. This kind of arrangement of flowers in called a **capitulum** or **head**. All plants of the family Compositae have heads. The head is really a spike with its rachis widened out into a disk to afford room for the flowers to be on it closely packed. Because of this crowding together, the flowers become small and, there-

fore, they are called florets. In a capitulum all the flowers may be alike as in *Vernonia* or, as is more common, the florets of the circumference known as **ray-florets** may differ in shape from those of the centre called **disk-**

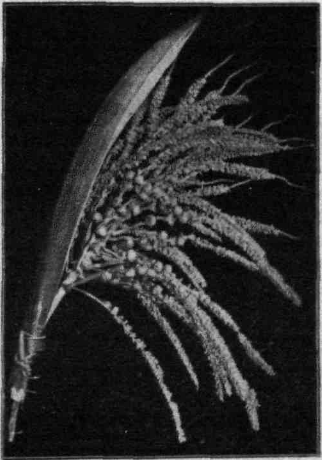


Fig. 75.—Coconut inflorescence.

florets. The ray florets are generally ligulate and the disk florets tubular. The florets are often embraced by small scaly structures called **palea**. The palea are really bracts. In a head outside the ray florets we find rows of bracts at the circumference. These bracts

constitute the **involucre**. The heads of sunflower, *Tridax* and *Zinnia* may be taken as examples.

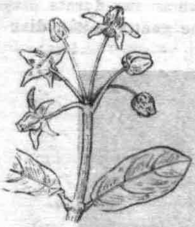


Fig. 76.
An umbel (*Calotropis*.)

In some plants the top of the peduncle expands into a flat horizontal disk and the flowers become small and are immersed as it were in the disk. Such inflorescences are fairly common in *Dorstenia indica* and they are called **coenanthia**. If the coenanthium becomes hollow, as in *Ficus*, then it is called a **syconium** or **fig**.

On comparing these four types of inflorscences above described, we find them differing in certain respects and resembling in certain general features. The raceme and the umbel both have pedicelled flowers, whilst in the spike and the capitulum flowers are sessile. In all these four, the youngest flower is at the top or at the centre and the oldest at the base or the circumference. Further, all the flowers are derived from the activity of the same growing point. The axis, where distinct, is a monopodium. So we may consider these four kinds of inflorescence as constituting a type and it is termed **botryose** or racemose. Owing to the continued activity of the growing point the number of flowers that could be formed is not limited. So this type of inflorescence is also called **indefinite**. It is also termed **centripetal**, because the order of flowering is from the circumference to the centre.

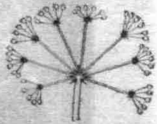


Fig. 77.—Compound umbel.

In some plants the terminal growing point of the axis, instead of producing flowers in succession, terminates in

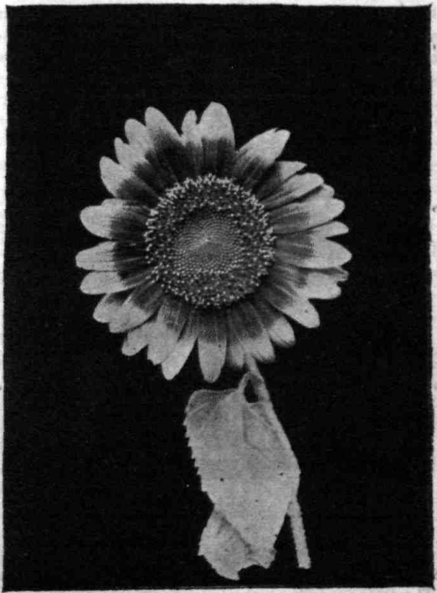


Fig. 78.—Sunflower (Head in flower.)

a flower which is the first to blossom. Below this, lateral branches arise and they also end in flowers. The

inflorescence in Jasmine plant is of this nature. In it we find a central flower with two lateral buds or flowers one on each side, the central one being older than the lateral. This really represents another type of inflorescence and it is called **cymose**. The order of flowering in this type being from apex to the base or centre to circumference,

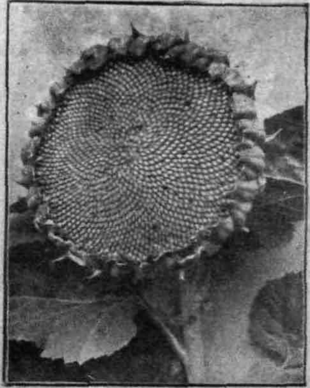


Fig. 79.—Sunflower (Head in fruit)

the inflorescence is called **centrifugal**. It is also called **definite**.

The cymose inflorescence also presents variations in its mode of development. The inflorescence in Jasmine consisting of only three flowers may be considered to be a **simple cyme**. But modifications occur. The lateral

branches, instead of bearing single flowers, possess in addition two flowers one on each side. In other words, the lateral branches are distinct simple cymes, one on each side of the central older flower. This may be repeated two or three to several times. Such inflorescences as these are met with in several species of *Ipomoea* and *Clerodendron*. In some plants, as in *Wrightia* and *Nerium*, this process is repeated indefinitely. If the development of the lateral branches is regular, the inflorescence is called a **dichasium**.

Fig. 80—Simple cyme of *Jasminum*.

The development of the lateral branches in the cyme is not always regular. Very often only one of the two lateral branches developes, and again the suppression of a branch may be regularly all on the same side, or it may be alternate. The former type of cyme is fairly common in some plants of the family Solanaceae and

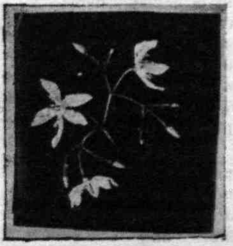


Fig. 81.—Dichasium of *Wrightia*.

the inflorescence is termed **a helicoid cyme.** The other type in which the suppression occurs alternately to the right and left, as in *Heliotropium* is called **scorpioid cyme.**

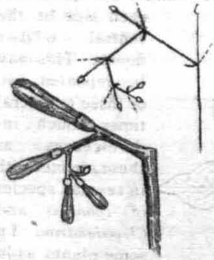


Fig. 82.—Helicoid cyme.

In both these varieties of cymose inflorescence the floral axis is coiled at the free end when young, but straightens itself later. The axis of the helicoid cyme when fully formed and straightened out looks like a raceme. But in reality it is a sympode and consequently the arrangement of the bracts would be different from that in a raceme. In a helicoid cyme the bracts when present will be opposite the flowers and in the scorpioid cyme there will be two rows of bracts.

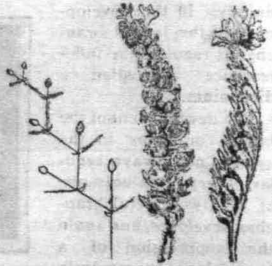


Fig. 83.—Scorpioid cyme.

Sometimes two cymes spring at the nodes opposite to one another, as in *Ocimum* and other genera in the family Labiatae. In some cases as in *Leucas* and *Leonotis* the cymes become condensed and overlap the axis and look like a whorl of

flowers ; so this kind of inflorescence is called a **false whorl** or **verticillaster.**

These two types of inflorescence, botryose and cymose, occur in plants generally, but in a plant only one of these types occur. In other words, a plant will have either botryose or cymose type of inflorescence and

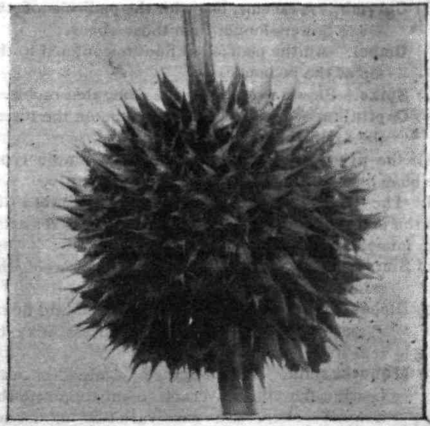


Fig. 84.—Verticillaster.

never either the one or the other indifferently. But in some plants, such as *Melia* and *Azadirachta*, the inflorescence may be a mixed one, the flowers being in cymes and the branches botryose. Such inflorescences are termed **panicles.** Several grasses have panicles.

The main kinds of inflorescence and their varieties may be tabulated as follows :—

A. The RACEMOSE TYPE (**Centripetal** or **Indefinite**). In this the growing point of the axis produces flowers in regular acropetal succession.

(1) **Raceme.**—Flowers on the elongated rachis all stalked and pedicels more or less equal in length.

(2) **Corymb.**—A raceme, but with the pedicels of the lower flowers longer than those above.

(3) **Umbel.**—All the pedicelled flowers confined to the top of the peduncle.

(4) **Spike.**—Flowers sessile on the elongated rachis.

(5) **Capitulum** or **head.**—Flowers sessile on the top of the axis, which enlarges into a disk.

All the five described above are of the simple type. We have also compound forms.

B. The CYMOSE TYPE (**Centrifugal** or **Definite.**) In this the main axis ends in a flower and lateral axes arise from immediately below.

(1) **Simple Cyme.**—The axis bears three flowers, the middle one being the oldest.

(2) **Dichasium.**—The axis ends in a flower and bears cymes on lateral axes. The process may be repeated.

(3) **Monochasium.**—An elongated sympodial axis bearing flowers, the bracts being opposite the flowers. There are two varieties of monochasium :—

(*a*) **helicoid**—the lateral branches develop on one side only regularly.

(*b*) **scorpioid**—the lateral branches develop alternately, right and left.

(4) **Verticillaster.**—Congested axillary cymes.

C. MIXED INFLORESCENCE.—**Panicle.**

CHAPTER VIII

THE FLOWER

A FLOWER is a distinct organ existing for the purpose of producing fruit and seed, after the process of fertilisation. The various forms and the differences in colour seen in flowers, no doubt contribute towards this supreme end. We find foliage leaves always in plants, but flowers appear only periodically. This is because the work of nutrition goes on continuously in a plant, whilst the process of reproduction is not a continuous one. Further, for the formation of flowers a large amount of nutritive material must be available, and this is possible only when vegetative activity precedes the formation of flowers. In other words, nutrition must precede propagation.

Flower buds arise in the axils of leaves or bracts, just like leaf buds. So the flower buds are homologous with the leaf buds, and a flower with a leafy branch. Sepals and petals borne by the floral axis are leaf-like in their origin and development. Although sepals and petals are found on the axis in circles, there are also instances of flowers in which they are spirally arranged, recalling to our mind the phyllotaxy of the foliage leaves. From what is said above, we should not think that the floral leaves are derived from or are modified foliage leaves. It was the general opinion among the older morphologists who confined their observations mostly to the flowering plants, that foliage leaves are primitive and that the floral leaves are derived from foliage leaves and that they underwent extensive modifications in the course of

evolution and began to develope sporangia, anther and ovules. But, in the light of what we know about the life-histories of the lower vascular cryptogams and Muscineae, this view cannot be accepted. The truth seems to be that the primitive leaves must have served both the purposes, vegetation and propagation. In the course of evolution differentiation must have taken place, so that a certain region of the shoot must have become purely vegetative forming only foliage leaves, while another produced sporangia.

The flowers of *Tribulus terrestris* with which we have already become familiar, may be studied closely with a view to learn the arrangement of parts and other general features in flowers. Judging from the construction of this flower, we find that a flower consists of an axis bearing at its swollen free end or the thalamus the four parts, namely, sepals, petals, stamens and the pistil in a definite order. The outermost part of the flower is the calyx and it consists of five, free, green, narrow members, the sepals. Since the sepals are attached to the floral axis around it at the same level, they are spoken of as forming a circle or a **whorl**. The petals constituting the corolla form the next whorl. They are yellow in colour. A flower in which the enveloping organs are in whorls or circles is said to be **cyclic**. These two organs of the flower are expanded and flat like leaves and serve the purpose of protecting the stamens and the pistil in the bud stage, and when in blossom are useful in securing pollination, if they are coloured. So the calyx and the corolla are only **accessory** organs, while the

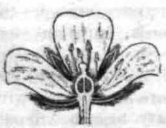


Fig. 85.—Longitudinal section of a flower of *Tribulus terrestris*.

stamens and the pistil constitute the **essential** organs. The sepals and the petals are collectively called the **perianth.** If these do not show much differentiation and look more or less alike, as if they formed a single series, the whole structure is termed a **perigone.**

The pistil is on the top of the thalamus in the *Tribulus* flower. Below this there are two whorls of stamens attached to the thalamus. The inner whorl consists of five longer stamens and these alternate with the five shorter outer whorl of stamens. At the base of the filament of each of the five shorter stamens there is a gland. As a general rule, in a flower the sepals alternate with the petals, the petals with the outer whorl of stamens and this with the inner whorl of stamens. In all cyclic flowers the various whorls alternate, if the whorls have the same number of members in each.

The *Tribulus* flower may be taken as an example of a typical, symmetrical, regular flower. It can be cut into two similar halves in more than one plane and hence it is **actinomorphic.** A flower is **typical** when it possesses all the four sets of organs, the stamens being in two whorls. It is described as a **regular** flower, when the members of the whorls are all alike in shape and size. To describe a flower as **symmetrical** it must have the same number of members in the enveloping organs, calyx and corolla, and need not be so in the essential organs.

On examining a large number of flowers from different species of plants it will be seen that differences in floral structure are due to considerable variations in the parts of flowers. We shall now consider these variations in detail.

Bracts.—Solitary flowers arise from the axils of ordinary foliage leaves, but flowers spring from the axils

of bracts in an inflorescence. Bracts are sometimes called **hypsophylls**, and they vary very much in shape, size and even in colour. These are usually small and scale-like in appearance. In some plants flowers do not have bracts. For instance, in the inflorescence of radish and mustard plants, bracts do not occur. The side of the flower towards the bract is **anterior** and the side towards the axis is **posterior**.

Besides the single bract from whose axil the pedicel springs, other bracts, usually two in number, occur higher up on the pedicel on the lateral sides of the flower. These are called **bracteoles**. In the flowers of *Dolichos Lablab* and *Clitoria Ternatea* bracteoles are clearly seen. When more than two bracts occur in whorls below the calyx, as in the flowers of cotton and *Hibiscus rosa-sinensis*, the whorl is called **epicalyx**. Often the bracts become aggregated at the margins of heads (see fig. 78 & 79) or at the bases of the pedicels in umbels. Then they are said to form an **involucre** and the bracts are **involucral** bracts. Bracts are very large and cover the whole of the inflorescence, as in many Aroids and palms, and then these are called **spathes**. In *Musa* there are many large bracts, each enclosing a series of flowers in two rows. There are also bracts that are coloured and then they are said to be **petaloid**. Such bracts occur in *Poinsettia*, *Bougainvillea* and *Combretum*.

The Calyx.—In the flowers of many plants the calyx is found outside or below the corolla, and it is the outermost whorl in a flower bud. The essential organs and the petals, when young, require protection, and this is afforded by the calyx. Generally it is green in colour, but in some plants, as in *Cassia siamea* and *Caesalpinia pulcherrima* it is coloured just like the petals and then it is **petaloid**. There are also flowers in which the calyx

does not exist. For instance, the florets in the heads of Compositae and the flowers of grasses are without the calyx. In these flowers protection to the essential organs is afforded by the bracts.

Fig. 85.—Spadix of *Musa.*

The calyx is usually simple and consists of a single whorl, and may be rarely double as in *Tinospora*, *Tiliacora*, *Cocculus* and *Berberis*. The component parts of the calyx or the sepals may be wholly free and then the calyx is **polysepalous**. When the sepals cohere by

their margins the calyx is **mono-** or **gamo-sepalous.** The degree of union may be to a very small extent at the base as in *Solanum*, or it may be throughout its margin so as to form a regular tube as in *Datura*, and we may have all gradations between these two extremes. Sepals may be prolonged at their backs into spurs, as in *Viola*. When the sepals are similar in shape and size, the calyx is **regular**, and it is irregular if the sepals are not alike, as in *Ocimum* and *Leucas*.

In the flowers that have expanded and opened the sepals and the petals may be present, but they fall after flowering and then they are said to be **deciduous**. It is not unusual for the sepals and petals to fall off as soon as the flowers begin to expand and open, and then they are said to be **caducous**. The sepals in the flowers of Poppy and *Argemone* are caducous. In some flowers the calyx persists without falling off, and then it is **persistent**. Often as in many Solanums, the calyx grows with the fruit and then it is said to be **accrescent**. The inflated calyx of *Physalis* is a good example of an accrescent calyx.

The Corolla.—Next to the calyx and immediately above it lies the corolla. Its members or the petals generally alternate with the sepals. The corolla is either simple consisting of only one whorl of petals, as in *Tribulus*, or it may have two whorls of petals as in *Argemone*. There are also flowers wherein the petals are many, as in *Nymphaea* and *Nelumbium*. In a flower the corolla is the most conspicuous and attractive part and it is usually coloured. The corolla varies more than the calyx. The petals may be free, as in *Tribulus*, *Hibiscus* and *Anona*, and then the corolla is said to be **polypetalous**. If on the other hand, the petals cohere by their margins, as in *Datura*, *Ruellia* and *Ipomoea* the corolla

is **mono-** or **gamopetalous**. The terms **choripetalous** and **sympetalous** are sometime used instead of polypetalous and gamopetalous.

The polypetalous corolla is generally very regular in most flowers. In some flowers it is irregular. For instance, the flowers in the family Papilionaceae have in them petals that are not all alike. The flower presents a definite pattern and it is divisible into two similar halves only in one plane and, therefore, it is said to be **zygomorphic** or bilaterally symmetrical. One of the five petals placed next to the axis is larger than the others and it is termed the **standard**. It encloses the remaining four petals in the bud. Of these, two lying one on each side, just below the standard, are alike in shape and size. This pair constitutes the **alae** or **wing petals**. The remaining two petals adhering by their lower margins are called **keel petals** or **carina**.

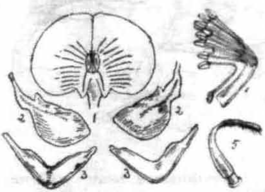


Fig. 87.—Papilionaceous corolla. 1, standard; 2, wing petals; 3, keel petals or carina; 4, stamens; and 5, pistil.

In a monopetalous corolla we can distinguish two parts, namely, the upper portion or the **limb** and the lower united part or the **tube**. The top of the tube is termed the **throat**. A tubular corolla whose tube insensibly widens upwards, as in *Datura*, is said to be **funnel-shaped** or **infundibuliform**. When the straight and the long tube abruptly ends in a flat spreading limb as in *Vinca* it is termed **hypocrateriform** or

salver-shaped. The corolla is **rotate** or **wheel-shaped** when the tube is suppressed and the segments are horizontal and divergent like the spokes of a wheel.

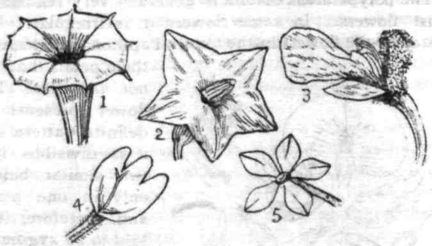


Fig. 88.—Forms of corolla. 1, funnel-shaped; 2, rotate; 3, labiate; 4, ligulate; and 5, hypocrateriform.

The corolla is rotate in some species of *Solanum*. It is **campanulate** if bell-shaped. If it becomes irregular and the limb is cut into two principal superimposed divisions called lips, then the corolla is **labiate**. The florets in the centre of a head have tubular corollas, whilst all round the margin we find florets in which the corolla consists of five confluent petals, of which two join only at the base and unite throughout their length with the three others, and hence strap-shaped. This kind of corolla is said to be **ligulate.**

The corolla, whether the petals are free or united, often bear appendages. The petals may have a nectary at the base of each petal, as in *Ranunculus*, or they may bear scales as in *Lepisanthes*, *Sapindus* and *Cardiospermum*. In monopetalous corollas the throat often bears numerous hairs as in *Thevetia*. In *Wrightia* the corolla has fimbriate scales united at the base in a ring. In the

throat of the corolla of *Nerium* we find a crown of long filamentous processes. These appendages are called **corona.**

The sepals and petals protect the stamens and the pistil in the bud and, therefore, they remain folded in the bud. This folding or **aestivation** is of interest,

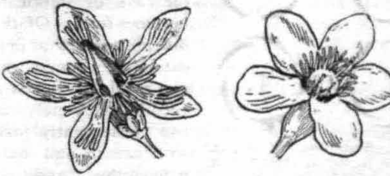


Fig. 89.—Coronas of corolla. 1, *Wrightia*, 2, *Nerium*.

because it is uniform and common to groups of plants or families. For instance, the petals of *Calotropis gigantea* touch each other by their margins and this mode of folding is **valvate.** The petals are said to be **contorted** or **twisted** when the front margin of a petal lies above the hinder margin of the petal before it and its hinder edge is covered by the front margin of the petal behind. In this kind of folding every petal has one of its edges covered and the other covering. The petals may be contorted to the right or to the left. (See fig. 90) Instead of this overlapping of the edges being regular, it is disturbed in some flowers. Of the five petals one or two often get pushed in or out completely, so that both the edges of the member thus disturbed are in or out. (See fig. 91.) This mode of aestivation is called **imbricate.** If we take into consideration the variations in the mode of imbrications we get forty modes. If we pay

attention to one petal assuming that both its margins are outside, and then consider all possible ways of folding of the remaining four petals, there are eight possible ways of folding (See fig. 91). As there are five petals the possible modes of aestivation in the case of imbrication becomes forty. Of these different modes of imbrication, the one in which two petals or sepals are outside completely and two consequently inside, with one in and out is noteworthy, and this mode is known as **quincuncial.** (See fig 91. E to H). The sepals of *Ipomoea* are quincuncial. In connection with aestivation, we have assumed that flowers are **pentamerous** in their

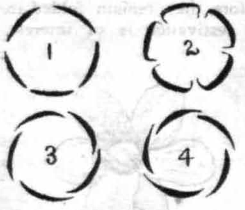


Fig. 90.—Aestivation. 1, and 2, valvate 3, and 4, contorted or twisted.

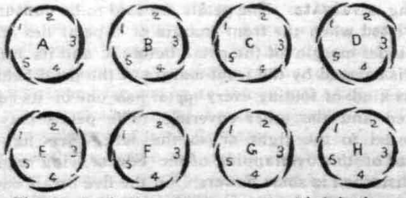


Fig. 91.—Aestivation. Different modes of imbrication.

enveloping organs, and this is so in the vast majority of plants. However, in some plants the flowers have three or four members in their perianth whorls. So the flowers may also be **tri-or tetramerous.**

Androecium or Stamens.—The stamens of a flower are collectively known as the **androecium.** The whorl of stamens may be single, double or more. A stamen consists of a stalk or **filament** bearing an anther at its free end. In the anther there are two lobes held together by the **connective**. In some flowers the anther may consist of only one lobe, as in the flowers of the plants belonging to the family of Malvaceae.

The position of the stamens on the floral axis relative to the other whorls varies. When the stamens spring from the thalamus below the base of the pistil, as in *Tribulus*, they are **hypogynous**. They are **perigynous** when the insertion is on the edge of the thalamus round and above the base of the ovary, as in the flowers of Peach, Rose and Pomegranate. When we find them inserted on the top of the ovary it is **epigynous.**

In some flowers the stamens are equal in number to the petals, as in *Ipomoea* and then the flower is **haplostemonous**. If the stamens are twice as many as the petals, then the flower is **diplostemonous.** We speak of the stamens as **indefinite** when there are more than twenty in a flower.

The stamens are not always equal in length. For instance, the stamens in the outer whorl in *Tribulus* are shorter than those of the inner whorl. In the flowers of *Linum*, *Oxalis* and *Biophytum* five stamens are long and five are short. In some species of *Ipomoea* the five stamens are of unequal lengths. The flowers of mustard and radish have six stamens of which two are short and opposite to one another, and four long placed in opposite pairs, and so the stamens are said to be **tetradynamous.** They are **didynamous** when there are four of which two are the longest. As examples we may mention the flowers of *Leucas*, *Tecoma*. and *Ruellia*.

In most flowers the stamens are completely independent of each other as in *Tribulus*, and then they are said to be **free**. However, in some flowers the filaments are more or less united in a single tube as in *Hibiscus vitifolius* and *Abutilon indicum*, and then the stamens are **mon-adelphous.** When united into two bundles as in *Sesbania grandiflora* and *Tephrosia villosa* they are **di-adelphous.** If the anthers cohere the filaments being free, the stamens are **syngenesious**. Such stamens occur in *Lobelia*, in all the flowers of the family Compositae and in the flowers of gourds and melons. The

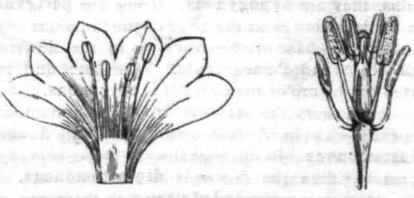


Fig. 92.—Didynamous and tetradynamous stamens.

stamens are **gynandrous** if they are attached to the pistil, as in the flowers of *Aristolochia* and orchids.

The anthers usually consist of two lobes, the lobes being held together by the connective, which is only a prolongation of the filament. As the connective varies very much in size and shape, the anthers present variations in their appearance and in the disposition of the lobes. In some flowers the anthers are attached to the filament by its base and then the anther is **basifixed.** It is **dorsifixed** when attached by the back and **versatile** when it moves freely, the anther being attached to the finely pointed end of the filament.

In an anther the lobes are usually parallel, as in *Datura*, *Solanum* and *Cassia*, but occasionally one lobe is inserted on the connective a little above the other, as in *Justicia*. Sometimes the connective is so short and small that the anthers are held together by a mere point. In some flowers the anther lobes diverge, being attached to the connective at one point. The connective is elongated into two unequal arms, and the longer one bears an anther and the other one may have a rudimentary anther or none. Occasionally the short arm may be absent. Such stamens are found in the flowers of *Ocimum* and *Salvia*. It is not unusual to find the connectives prolonged beyond the anther lobes and forming glands, scales or tails, as in *Neptunia*, *Ionidium* and *Nerium*. The filaments also have appendages in *Calotropis*. All these appendages are called **corona**.

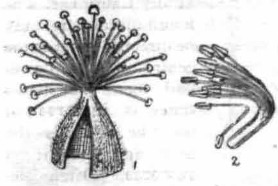


Fig. 93.—Mon- and di-adelphous stamens. 1, *Abutilon*; 2, *Crotalaria*.

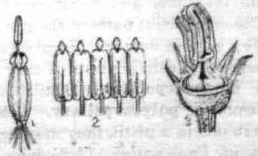


Fig. 94.—Syngenesious anthers. 1, and 2, *Tridax procumbens*; 3, *Cucurbita maxima*.

The anthers dehisce in most flowers longitudinally either from above downwards or the reverse. In

Solanum they open by apical pores, that is to say, th suture opens just at the top. We also have anthers oper ing by means of valves, as may be seen in the flowe of *Mahonia*, *Berber* and in those of th family Laurineae. Th longitudinal slit ma be directed towards th centre of the flowe and then the dehis cence is **introrse**; i may be towards th petal and then it i **extrorse**. Often th opening is lateral Horizontal and circula dehiscence of anthers are not uncommon.

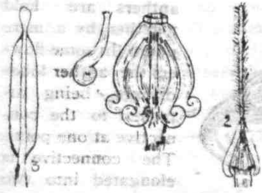


Fig. 95.—Staminal coronas. 1, *Calotropis*. 2, *Nerium*: 3, *Nelumbium*.

Gynaeceum or the Pistil.—The gynaeceum crowns the thalamus and occupies the centre of the flower The component parts of the pistil are called **carpels** anc they vary in number. In plants of the family Legumi nosae the pistil consists of only one carpel and hence i is **monocarpellary**. Pistils having more than on carpel are **polycarpellary**. When the carpels are mor than one in a pistil, they may be free without cohering as in *Ranunculus*, *Thalictrum*, *Polyalthia* and *Bryophyllum*. In this case the pistil is termed **apocarpous** The carpels become united into a single body in mos cases, and then the pistil is **syncarpous**. The ovarie alone are united in *Linum*, and the union extends to th top up to the stigma in *Tribulus*, *Ipomoea* and *Solanum* In *Calotropis* the stigmas and the upper portion of th styles are united, the ovaries being free.

When the pistil consists of a single carpel only, as ir

Crotalaria verrucosa, and *Dolichos Lablab*, the edges of the carpel are folded and united, and this edge becomes thickened and bears ovules. The thickened edge is called the **placenta**, and in this case it is really double, which becomes obvious when the pistil is opened, and then it splits into two partially seed-bearing placentas. The suture bearing the ovules is termed the **ventral** and the opposite one is called the **dorsal** suture. When the pistil consists of more than one free carpel, the edges of the carpels are folded inwards and become united towards the centre of the flower.

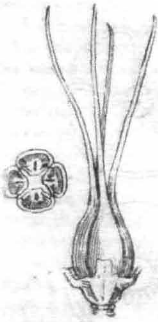


Fig. 96.—Apocarpous ovary of *Bryophyllum*.

The syncarpous ovary is the result of the union of the carpels of the ovary, and this union may take place in two ways. The edges of the carpels meet at the ends and unite and in this case, whatever may be the number of carpels, there will be only one chamber, but the number of placentas will be the same as the number of carpels. It must be remembered that each of the complete placentas belong to two contiguous carpels, one half of each. The union takes place also by the edges folding inwards so as to form vertical partitions, each composed of two confluent plates called septa, belonging to different carpels. In this case the ovary will have as many chambers as there are carpels. Generally the number of carpels in a syncarpous pistil is inferred by the number of stigmas or the styles when they are free, or by the number of placentas. For instance, the ovary of

Ionidium consists of three carpels, as there are three placentas, although there is only one chamber. As the edges of the carpels touch and unite, the placentas are found on the wall of the ovary and this placentation is called

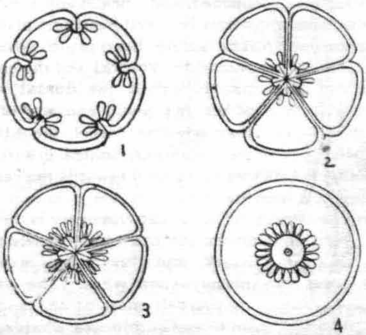


Fig. 97.—Different modes of Placentation. 1, parietal; 2, and 3, axile; and 4, free-central.

parietal placentation. In the ovary of *Argemone* there is only one chamber bounded by its wall or the pericarp, but there are four or five placentas. Hence the ovary is four or five-carpelled. In an ovary in which the margins of the carpels project into the ovary and divide it into chambers the placentation is **axile**. The whole of the placenta in a chamber belongs to the carpel which forms the chamber, because the margins that meet at the centre belong to the same carpel. We have in some ovaries a free-central axis, not connected with the pericarp by partitions, bearing the placentas. The ovules

are attached all round the free-central axis and, therefore, this is called **free-central** placentation. When there are only a few ovules they may be pendulous, as in *Terminalia* and *Quisqualis*, or erect as in *Celosia* and *Polygonum*.

The ovary is termed **superior** when it is above the other whorls in the flower and not adherent to any of the neighbouring parts. It is **inferior**, if it is placed apparently below the stamens, corolla and calyx.

In an apocarpous pistil, each carpel is prolonged above into a style ending in a stigma, and when the pistil is completely syncarpous it has only one style and stigma. The style usually springs from the top of the ovary and then it is terminal. It may be lateral, as in the pistil of the Jack tree.

The style is said to be **gynobasic** when the base of the style is somewhat dilated and extends below the ovaries, as in *Ocimum*, *Anisomeles* and *Leucas*. Sometimes the style is branched at the free end as in *Abutilon* and *Hibiscus*.

The **Thalamus or Torus**.—The thalamus is the apex of the pedicel situated between the calyx and the gynaeceum on which the corolla and stamens are inserted. Besides bearing the stamens and the petals, the thalamus produces in some flowers glands. In many plants the torus develops an annular ring or a **disk**, as in *Ipomoea*, *Crotalaria* and *Dolichos*. It usually secretes honey and so it is a nectary.

As a rule in primitive types of flowers, the thalamus is somewhat round or conical and bears all the whorls without any interval. For instance, in *Ranunculus*, *Tribulus* and *Argemone* the thalamus is only a rounded body. Occasionally the floral axis becomes elongated so that there is an interval between the series of parts.

In *Gynandropsis pentaphylla* the pistil and the stamens are carried up a considerable distance above the sepals and petals. This elongated part of the thalamus or the floral axis is called **gynandrophore**, or a stalk bearing the gynaeceum and the androecium. In species of *Capparis* and *Cadaba* the pistil alone is raised on an elongated axis. This elongated stalk of the ovary is called **gynophore**. Frequently, the thalamus widens out and forms a flat structure or a broad or narrow cup.

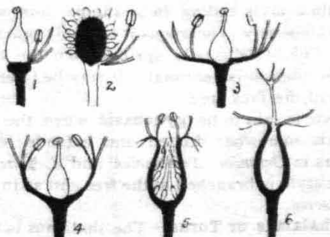


Fig. 98.—Modifications of the thalamus. 1, ordinary type; 2, swollen thalamus; 3, disk-shaped thalamus; 4, and 5, hollow thalamus; 6, hollow and fused thalamus.

For instance, in the sunflower the receptacle of the whole inflorescence becomes a flat disk. In the flowers of *Zizyphus* the thalamus forms a shallow cup and the ovary also gets immersed in an annular lobed disk which is an outgrowth of the thalamus. The very shallow cup from the bottom of which the pistil arises in the flowers of *Caesalpinia* and *Cassia* is thalamus hollowed out. When the thalamus forms an open flat plate or a cup, the stamens, petals and the sepals are borne by the

edge of the expanded thalamus. The position of the pistil however is not affected. It still maintains its usual position, that is so say, it remains in the centre of the flower and on the top of the thalamus. As examples of flowers in which the thalamus is cup-shaped we may mention the flowers of Peach, Rose, and Pomegranate. When the torus is flattened or cup-shaped the sepals, petals and the stamens are inserted round the edge of the thalamus. Hence they are not underneath the gynaeceum, but round about it. This gives rise to the perigynous condition. In this condition the carpels or partially adherent. They are free in the Peach and Rose and partly adherent in the pomegranate. A more important modification is that in which the thalamus is cup-shaped, leading to the 'sinking of the gynaeceum downwards into the tissue of the hollowed-out thalamus. In this case the inner-surface of the thalamus cup fuses with the outer-surface of the pericarp. This results in the epigynous condition with inferior ovary.

As has already been remarked in a typical Angiospermic flower the parts are arranged in five alternating whorls, of which two form the perianth, two the stamens, while the gynaeceum consists of one whorl. The flower is **pentacyclic** because it has five cycles. It is **pentamerous** as it has five members in each whorl in most dicotyledons, and **trimerous** as it has three members in each in monocotyledons. The number of members in each whorl is either the same, or there is an increase or decrease, especially in the androecium and the gynaeceum. The significance of this decrease or increase will be referred to later on.

Flowers may have both the essential organs in the same flower, as in *Tribulus* or they may be found on different flowers, as in *Cucurbita* and *Coccinea*. In the

former case the flowers are **bisexual** or **hermaphrodite** and in the latter **unisexual** or **diclinous**. A unisexual flower is **staminate** or male if only stamens are present. When it bears the pistil only it is a female or **pistillate**

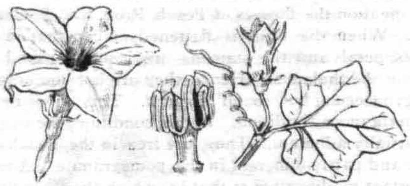


Fig. 99.—Unisexual flowers of *Coccinea indica* (a dioecious creeper.)

flower. When flowers are diclinous, both the staminate and pistillate flowers may be present on the same plant, as in *Cucurbita* and then the plant is said to be **monoecious**. If the pistillate and staminate flowers are borne by different individuals, as in *Coccinea* then the plant is **dioecious**. Some times we may have hermaphrodite and unisexual flowers occurring on the same plant and such plants are **polygamous**.

Floral diagrams.—To learn the parts of a flower and their disposition in it, we should examine not only the flower but also a flower bud. If we take a transverse section of a bud, we see not only their parts but also their arrangements with reference to one another. (See fig. 100.)

It is usual to represent these sections in a diagrammatic manner, and such diagrams are called floral diagrams. This is a most convenient method for showing clearly the positions of the various parts of the flower. The floral

liagram is really a number of concentric circles corres-
>onding to the number of whorls. On them the positions
is well as the union of the parts of each whorl are shown.

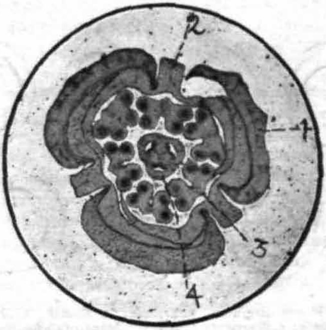


Fig. 100.—Transverse section of a bud of a Lily. 1, Sepals; 2, petals; 3, stamens; 4, ovary.

The position of the floral axis and that of the bract are
ilso indicated in the diagram. (See fig. 101.)

It is also usual to show the position and arrangement
of parts of a flower by a **floral formula**. This gives a
very brief expression for the parts as shown in a floral
diagram. The calyx, corolla, androecium and gynaeceum
are represented by the letters, K, C, A and G respectively.
The number of members in each whorl is placed after
the letter. The cohesion of the members of a whorl is
shown by enclosing the proper number within ordinary
brackets, thus, C(5) which means a monopetalous corolla
of five petals. Two whorls of the same kind are repre-
sented by repeating the number with a plus sign between.

When there is a large number of members in any of the whorls it is denoted by the symbol ∞. The superior or inferior position of the ovary is indicated by placing

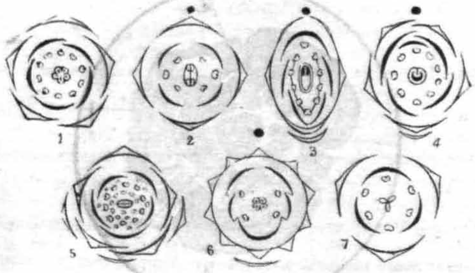


Fig. 101.—Floral diagrams. 1, *Tribulus*; 2, *Radish*; 3, *Dolichos*; 4, *Caesalpinia*; 5, *Guava*; 6, *Leucas*; 7, *Monocotyledon.*

a horizontal line below or above the number representing the carpels. The floral diagrams given in fig. 101. may be expressed by floral formulae as shown below.

Tribulus	—K 5.	C 5.	A 5 + 5.	G (5).
Radish	—K 2 + 2.	C 4.	A 2 + 4.	G $\underline{(2)}$.
Dolichos	—K (5).	C 5.	A 1 + 9.	G $\underline{1}$.
Caesalpinia	—K 5.	C 5.	A 10.	G $\underline{1}$.
Guava	—K 5.	C 5.	A ∞	G $\underline{(2)}$.
Leucas	—K (5).	[C 5.	A 4].	G $\underline{(2)}$
Lily	—K 3.	C 3.	A 3 + 3.	G $\underline{(3)}$

CHAPTER IX

THE ESSENTIAL ORGANS AND THEIR FUNCTIONS

ALTHOUGH the function of the flower is the production ıf seeds, the parts of the flower directly concerned in his work are the essential organs, androecium and the ;ynaeceum. The formation of the seed involves two listinct processes, namely, **pollination** and **fertilisation**. 'he conveyance of the pollen-grains from the anther to he stigma or the receptive surface at the distal end of he gynaeceum is pollination. As soon as the pollen-rain reaches the stigma it germinates, forms a ıollen-tube, which penetrates the style and reaches the vule. A bit of specialised protoplasm or a nucleus ıasses from the pollen-tube into the interior of the ovule. Vithin the ovule a nucleus is specialised as the **egg-cell** r **ovum**, and with this the nucleus from the pollen-tube ıses. This fusion of the two nuclei from two distinct ources is fertilisation. After this, the cell, the resultant f the fusion divides and develops into the seed.

Stamens are the organs that produce the pollen-grains. Ve already know that pollen is formed within the an-ıers. An anther is two-lobed and the lobes are attached ıterally to the connective, through which a vascular ıundle runs. The stamens of *Tribulus terrestris* may e studied for its structure, as it is typical of the anthers f a large number of plants. When young each of the wo anther lobes will have two **locules** or **pollen-sacs**, ıll of pollen. If a transverse section of an anther is xamined it will be seen that the wall of the anther con-

sists of an epidermis and a layer of fibrous cells beneath it. At the place where the walls of the pollen-sacs join with the septum that separates them, the fibrous layer is not formed. At this point and all along the length of the anther lobe, all the cells are rounded and thin-walled, with intercellular spaces. This arrangement is intended to facilitate the dehiscence of the anther when ripe along this line.

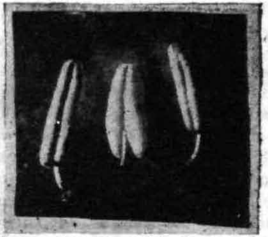


Fig. 102.—Stamens of *Tribulus terrestris*.

When young the anther lobes are rigid and full and their outer surfaces are unbroken. The cells of the epidermis bulge slightly outwards and they are filled with protoplasm. And it is these young epidermal cells that maintain the turgidity. Until the **pollen-grains** are fully developed, the epidermal cells are turgid and are in a living condition, exerting pressure on the fibrous cells. When the pollen-grains are mature the epidermis loses water, and the

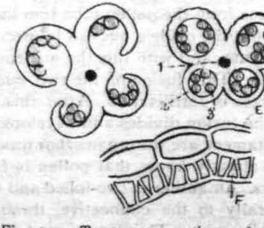


Fig. 103.—Transverse sections of the anthers of *Tribulus terrestris*. 1, vascular bundle; 2, anther-wall; 3, pollen-grains; E, epidermal cell; F, fibrous cells.

fibrous cells expand and bring about dehiscence. The presence of the fibrous layer and the absence of these cells along the line in front of the septum are conducive to dehiscence. As soon as pollen is shed, the stamens fall away, as they are of no further use.

Just like the flower, the pollen-grains also vary very considerably in size, shape, colour and in the marking on the outside. All these differences are only external.

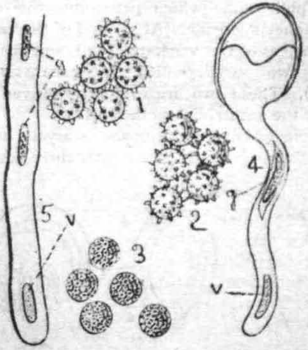


Fig. 104.—Pollen-grains and pollen-tube. 1 and 2, Pollen-grains of *Hibiscus* and *Thespesia*; 3, Pollen-grains of *Tribulus*; 4, Pollen-grain germinating; 5, the end of the pollen-tube; v, vegetative cell; g, generative nuclei.

The internal structure is more or less uniform in character, whatever the external differences may be. A pollen-grain is essentially a bit of protoplasm differentiated into two cells, one being larger than the other. It has

two coats, the **intine** and the **extine**. Generally the former is uniform, thin and smooth, whereas the latter is cuticularised and sculptured in various ways. Of the two cells, the larger one is called the **vegetative** cell and it is this cell that gives rise to the pollen-tube. The smaller cell consists of cytoplasm and a nucleus and this cell takes a direct part in the reproductive process. It is called the **antheridial mother-cell.**

When the pollen-grain germinates on the stigma it forms a pollen-tube which penetrates the style and finally reaches the ovule. At the end of the pollen-tube lies the nucleus of the vegetative cell and just above it are seen two nuclei, called the **generative nuclei (gametes)**. These two are evidently derived from the nucleus of the antheridial mother-cell.

The ovule which is within the ovary is usually attached to the placenta by means of a short stalk called

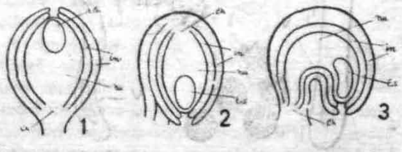


Fig. 105.—Different forms of ovules. 1, Orthotropous; 2, anatropous; 3, campylotropous; ch, chalaza; in, integument; nu, nucellus; E.s, embryo-sac.

the **funicle**. In form ovules are oval. An ovule consists of a mass of cells called the **nucellus**, invested almost completely by one or two integuments, except for a small passage termed the **micropyle**. The base of the ovule from which the integuments arise is called the

chalaza. Variations occur in the ovules as regards their position on the placenta. In some plants the ovules are erect or **orthotropous** as in *Polygonum*. In this case the ovule is in direct continuation of the funicle. The chalaza and the micropyle are far apart and opposite to one another. (See fig. 105.) The body of the ovule may become bent on itself, as in mustard and radish

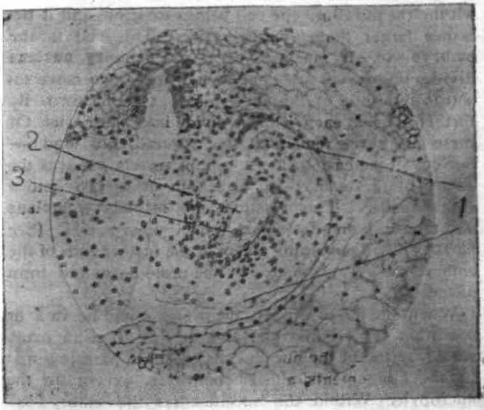


Fig. 106.—Longitudinal section of an ovule of the Lily in which the primary nucleus has become divided into two nuclei. 1, ovule; 2, embryo-sac; 3, nucleus.

and then it is said to be **campylotropous.** In this form of the ovule the micropyle and the chalaza lie near the funicle. But the commonest form of the ovule is the **anatropous** condition i. e., ovule inverted. In this

the micropyle would be opposite to the chalaza but close to the hilum, the funicle being adherent to the integument on one side.

In the early stages of development the ovule arises from the placenta as a mass of cells and later this forms the nucellus or the chief part of it. After sometime this *nucellus* becomes covered by the growth of one or two integuments from the base of the ovule. Sooner or later, within the nucellus, one cell begins to grow and it becomes larger than all the others. This cell is the **embryo-sac**. Its nucleus called the **primary nucleus** divides into two at first, and each of these two move towards the ends of the embryo-sac. (see fig 106.) By further division each of these divide into four nuclei. Of these four three remain at the extreme ends, and one nucleus from each of these groups travels towards the centre of the embryo-sac and both these fuse into a single nucleus. This is termed the **secondary nucleus** and the two before fusion are termed polar nuclei. (See fig 107.) The remaining nuclei at the farther ends of the embryo-sac get surrounded by the protoplasm and form naked cells.

When the flower is open, the ovules would be in a fit condition for fertilisation, and at this stage an ovule would consist of the nucellus, its essential part, invested by the integuments almost completely except for the micropyle. Within the nucellus lies the embryo-sac with the seven naked cells arranged as described above. The three cells at the micropylar end constitute the "egg-apparatus" and the larger inner cell of this group is the **ovum** or **egg-cell**. The other two cells, just above and close to it are called the **synergids**. The remaining group of three cells at the chalazal end of the sac is called the **antipodal** cells.

The pollen-grain begins to show its activity as soon as it is deposited on the stigma. The structure of the stigma and its condition at the time of the reception of the pollen-grains are adapted to facilitate the germination of the pollen-grains. On germination the pollen-grain forms a tube. At first the contents of the

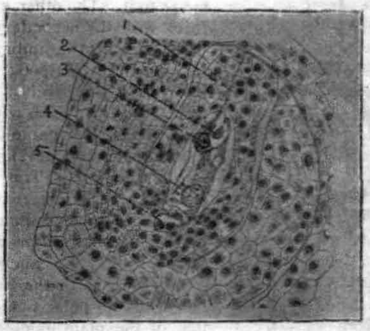


Fig. 107.—Longitudinal section of an ovule of the lily. 1, Micropyle; 2, synergids; 3, egg-cell; 4, secondary nucleus; 5, antipodal cells.

vegetative-cell passes into the pollen-tube and then the nucleus and the cytoplasm of the antheridial mother-cell get into it. The nucleus of the latter divides into two nuclei or **male gametes**. So the nucleus of the vegetative cell will be near the end of the pollen-tube and the two male gametes behind this.

The pollen-tube traverses the style and reaches the ovule, getting the nourishment for its growth from the

tissue through which it passes. Entering the micropyle it reaches the top of the nucellus where the egg-apparatus lies. Then the two male gametes, already formed in the pollen-tube, pass into the embryo-sac. One of them fuses with the egg-cell or ovum, the synergids probably helping in directing the gametes to it. The other gamete fuses with the secondary nucleus lying in the embryo-sac between the antipodal cells and the egg-apparatus. The ovum after its fusion with the male gamete is capable of further division and development into the embryo. The fusion of the second gamete with the secondary nucleus generally takes place long after the fusion of the polar nuclei. In some cases, as in the lily, the fusion of the polar nuclei and that of the male gamete may take place simultaneously. The secondary nucleus after this commingling with the male gamete, divides and gives rise to the endosperm. In many plants after fertilisation the greater portion of the nucellus tissue disappears, and between the seed coats and the embryo nothing remains. But in the case of a few plants, as in pepper and water lily, the nucellus tissue persists and does not get absorbed. This nucellus tissue persisting in the seed is the **perisperm.**

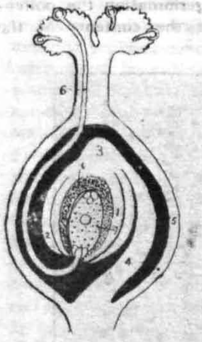


Fig. 108.—Diagram to illustrate pollination and fertilisation. 1 and 2, integuments; 3, chalaza; 4, funicle; 5, pericarp; 6, nucellus; 7, embryo-sac.

The tip of the pollen-tube, as a rule, enters the

micropyle of the ovule and reaches the nucellus in the vast majority of plants. This entrance of the tube through the micropyle is termed **porogamy**. In some plants, as in *Casuarina*, the pollen-tube enters the ovule at the chalaza and reaches one of the many embryo-sacs in the nucellus. This mode of the entrance of the pollen-tube into the ovule is called **chalazogamy**. Chalazogamy is now known to occur in many plants belonging to the families, Ulmaceae, Urticaceae and Euphorbiaceae.

The time that elapses between pollination and fertilisation is generally very short, although this interval may extend to one year in the case of some gymnospermous plants. Thus it is clear that in Angiosperms a seed is formed only after this double fertilisation. Further details as to the significance of this fusion and its influence on the embryo are dealt with elsewhere.

We now know that for the formation of seeds pollen is absolutely necessary, because the male gametes fertilising the ovum and the secondary nucleus are formed in the pollen-grains. In consequence of the higher plants being rooted to a place and the pollen-grains being incapable of movement, some extraneous aid is necessary for the conveyance of pollen. Even in the case of hermaphrodite flowers pollen-grains have to be carried to the stigma. The agencies that are made use of by plants for pollination are wind, insects and water. The conveyance of pollen-grains of a flower to its stigma or to the stigmas of flowers on the same plant is **self-pollination**. If the pollen is carried to the stigmas of flowers on a different individual it is **cross-pollination**.

The vast majority of plants have hermaphrodite flowers and so it may be assumed that no special arrangement would be necessary for pollination. But

extended observation shows that adaptations of very complex nature exist and that all the manifold modifications of the flowers of Angiosperms are meant to facilitate pollination.

Although cross-pollination is more advantageous to plants than self-pollination, there are several plants in which self-pollination is very common. For instance, the chenopodiums have flowers that are self-pollinated. Generally self-pollination occurs in plants having inconspicuous flowers with sticky pollen. There are flowers

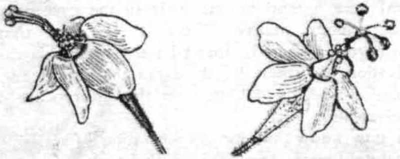


Fig. 109.—Flowers of *Hibiscus micranthus*.

having the stigmas and the anthers far enough apart to make self-pollination impossible when they first open. Later, however, the anthers and the stigmas come into contact. As an example for this we may mention the flowers of *Hibiscus micranthus*. In this flower, just when it opens, the stigmas project far above the anthers and so the pollen cannot reach the stigma. If the stigmas do not receive foreign pollen they bend down, so as to come in contact with the anthers in the same flower, and thus self-pollination is effected. Other flowers, having this kind of adaptation in their floral mechanism to secure self-pollination if cross-pollination fails, are those of several species of Malvaceae and Compositae, *Mirabilis jalapa* and *Evolvulus alsinoides*.

Self-pollination or autogamy usually occurs in the flowers of many plants. Many of the weeds, especially annuals, are holding their own in most places and become dominant because they are usually self-pollinated and do not need any extraneous aid for pollination. In plants, in which self-pollination is the rule, cross-pollination may occasionally occur, thus enabling them to keep up their strength and fertility. There are some plants which unite the two methods by producing ordinary showy flowers and also inconspicuous closed or **cleistogamous** flowers. For example, *Commelina benghalensis* produces pretty blue flowers that are very conspicuous and also white inconspicuous flowers which are underground. The former are cross-pollinated and the latter are self-pollinated. In *Viola* and *Arachis hypogaea* also cleistogamous flowers are known to occur.

Fig. 110.—Cleistogamous flowers of *Commelina benghalensis.*

In spite of the fact that the vast majority of plants possesses hermaphrodite flowers, cross-fertilisation appears to be more common, and the adaptations to favour this method in preference to self-pollination are indeed many. Even in flower in which self-pollen

may not be entirely sterile, self-pollination is made difficult if not altogether impossible. When plants are monoecious or dioecious self-pollination is out of the question.

In many a plant self-pollination is rendered impossible by the essential organs attaining maturity at different times. This condition is usually known as **dichogamy**. The stamens ripen very much earlier than the stigma of the same flower so that the pollen can be useful only for cross-pollination. Such flowers as these are **protandrous**. Flowers of Compositae, Malvaceae, Geraniaceae and Umbelliferae are protandrous. In some flowers, as in *Pennisetum typhoideum*, stigmas mature earlier than the stamens, and these flowers are **protogynous**. Such flowers are common in some species of *Euphorbia* also. Protandry, however, seems to be more common than protogyny.

From experiments of Charles Darwin it is obvious that cross-pollination is more advantageous to a plant than self-pollination. It is a well-known fact that in some plants self-pollination results in a very poor yield or they are sterile. In orchids self-pollination kills the flower. If both foreign and self-pollen are deposited on the stigma of a flower, the foreign pollen-grains germinate more readily than self-pollen.

A large number of spermatophytes depend for their pollination on the wind. For instance, in all grasses and many deciduous trees the pollen is wafted on to the stigma by the wind. Such plants are called **anemophilous** plants. Where use is made of wind for the conveyance of pollen-grains to the stigma, we notice certain features in the flowers that should be considered as special adaptations to favour pollination. In the first place wind is proverbially ûnsteady and as such the

pollen-grains that may be blown on to the stigma cannot be very many. Consequently, to minimize the chances of failure and to effect pollination with certainty, a large amount of pollen is usually formed in the flowers of anemophilous plants. The pollen-grains also are light, dry and smooth. The stigmas also in such flowers are

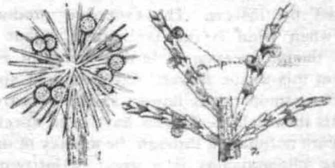


Fig. 111.—Stigmas of 1, *Hibiscus* and 2, of a grass plant.

plumose and very much branched so as to offer the largest amount of surface for the reception of pollen. The anthers also are so attached to their filaments that they may be shaken and made to shed their pollen even when slightly disturbed by the wind. The anthers are, in other words versatile.

The inflorescence, as may be seen in all grasses and cereal plants, is usually lifted far above the level of the foliage. In deciduous trees flowers occur long before the appearance of the leaves. This is advantageous, because there is nothing to impede the passage of the pollen. The tree *Odina wodier* is bereft of leaves when in flower. It must also be noted that anemophilous plants are devoid of scent and colour. The occasional occurrence of a reddish colour in certain anemophilous plants is not intended for pollination, but is said to help the plant in absorbing heat-rays.

In this connection it must he noted that flowers producing pollen in abundance are more primitive than those in which the stamens are few and hence producing a small amount of pollen. The earlier seed plants were evidently related to the cone-bearing plants represented at the present time by pines and cycads. The anemophilous plants are, therefore, more primitive than those pollinated by insects. The excessive production of pollen when wind is the pollinating agent is very wasteful though necessary. In the course of evolution, to prevent this waste, flowers have adopted specialisation. The gamopetalous flowers and orchids are evidently plants in which the flowers have been specialised so as to secure pollination through the agency of insects.

Among phanerogams in a great majority of plants pollination is effected by insects, and such plants are known are **entomophilous** plants. The insects that usually visit flowers are bees, flies, butterflies and moths. All these insects have sucking apparatus, which in the case of flies and bees are short and in butterflies and moths they are long and coiled like a spring. All these insects visit the flowers, because they find in them honey and pollen. Both these substances are eagerly sought by bees as food, but butterflies and moths drink only honey.

As a rule insects effect cross-pollination and for the success of this process, flowers should be regularly and systematically visited by them. If the visits to the flower are irregular and only casual, or if the insects choose flowers indiscriminately pollination cannot take place to any advantage. As the secretion of honey and the exposure of pollen always occur when the flowers open, regular visits of insects are ensured. The presence of colour and scent in the flowers, when they blossom

forth, are further attractions for the insects. By careful observation it will be seen that an insect generally confines its attention to the kind of flower for a long time, with which it begins its visit. A carpenter bee was once seen while sucking honey from the flowers of *Bauhinia tomentosa* and it continued to seek the same flower for over an half-hour, avoiding all the flowers that were near. At another time its visits were confined to *Dolichos Lablab* flowers. Butterflies, on one occasion, began their visits with *Justicia* and *Tephrosia* and continued to do so for over an hour.

Flowers pollinated by insects produce only a small quantity of pollen and so stamens are usually fewer in number. The pollen-grains have rough surfaces and are studded with spines or other devices and are usually sticky. *In short, the various adaptations, particularly in flowers that are specialised, are so perfect that pollination is a certainty.*

Flowers that are actinomorphic and shallow and those with short tubes are usually visited by a large number of insects. For example, in the *Tribulus terrestris* flower honey is secreted by glands at the base of the stamens and between the petals. The stamens are erect and are about the same height as the stigma when the flower is open. So any insect can get at the honey, and at the same time its body will be dusted with pollen and that pollen-dusted part of the body will come in contact with the stigma of another *Tribulus* flower, when it goes to it. The flowers of *Tridax* and *Taraxacum* are usually visited by a number of insects. At least a dozen kinds of insects may be seen to visit the former and in the case of the latter, one observer records that about one hundred kinds of insects are known to visit it.

Flowers with long tubular corollas such as those of

Ipomoea, *Jasminum* and *Vinca* and papilionaceous flowers are not visited by many insects, because the honey is hidden and only long-tongued insects can get at it. All these flowers are highly specialised for cross-pollination by particular insects. A careful observation will reveal a definite adjustment existing between the floral mechanism of these flowers and the kind of insect visiting them. In these flowers the nectary will be so situated and the arrangement of the parts would be such that an insect cannot get at the honey, without some part of its body brushing against the pollen in the anthers. For successful cross-pollination by the visits of the insect, it is absolutely necessary that the part of the body of the insect that gets dusted with the pollen should also come into contact with the stigma.

Colour of petals, though intended to show off well by contrast, is probably not capable of attracting insects so well, as the scent of flowers and the smell of honey. For example, the flowers of *Mirabilis jalapa* are visited by hawk-moths during evenings even after dusk. There are several varieties of this plant and the colour of the flowers are white, cream, yellow, red and magenta. In all the varieties the flowers open only towards the evening and they emit a strong scent. In the dusk flowers that are white, light-yellow or cream-coloured alone can be seen and the red and magenta flowers cannot be seen, judging from our own experience. Yet the moths visit the flowers of all colours with equal ease.

As already stated, some flowers are highly specialised and can be pollinated only by the visits of particular kinds of insects. As examples, we may consider the flowers of *Crotalaria verrucosa*, *Phaseolus trilobus* and *Habenaria platyphylla*.

The flowers of Papilionaceae are specially adapted

for cross-pollination in several species. In *Crotalaria verrucosa* there is a disk round the ovary at the base secreting honey, and this honey flows into the staminal tube. As the staminal tube and the ovary are within the keel petals, insects cannot easily get at the honey. The wing petals are spread out at the sides just above the keel petals so as to form a platform for the insects to sit on. The standard is generally very conspicuous and it

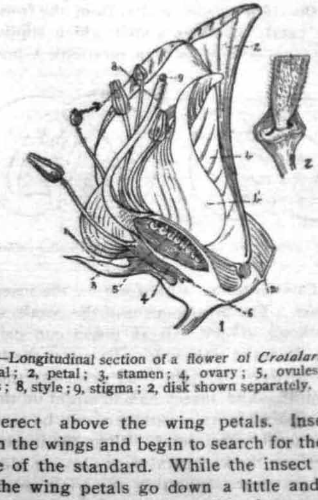


Fig. 112.—Longitudinal section of a flower of *Crotalaria verrucosa*. 1, Sepal; 2, petal; 3, stamen; 4, ovary; 5, ovules; 6, disk; 7, anthers; 8, style; 9, stigma; 2, disk shown separately.

stands erect above the wing petals. Insects settle down on the wings and begin to search for the honey at the base of the standard. While the insect is moving about, the wing petals go down a little and press the keel petals. This causes the pollen dust to be ejected from the tip of the keel petals, and some pollen dust

must necessarily fall on the body of the insect. This ejection of the pollen can be very well seen in the flowers of *Crotalaria juncea* when they are visited by bees. At first in one flower the bee gets dusted with pollen and, when it goes to another flower, the stigma touches that part of its body which is covered with pollen.

In the flowers of *Phaseolus trilobus* the keel petals are prolonged into a spiral beak, and the end of the spiral is towards the right side, looked at from the front. The right keel petal possesses a spur which supports the right wing petal and helps it in retaining a horizontal

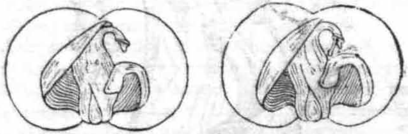


Fig. 113.—Front view of the flowers of *Phaseolus trilobus*.

position. This serves as a platform for the insect visiting the flower. The arrangement of the petals, stamens and the stigma is such that an insect can get at the honey only from the right side. To get at the honey it has to pass between the right wing petal and the end of the keel-spiral. The insect has to alight on the lower wing petal and when it does so there will be some pressure exerted on the keel petal. When the insect moves on the platform the keel petal must also get depressed because of its spur supporting the wing petal. This depression causes the stamens and the stigma to pop out at the end of the spiral. If the insect visits a flower

at first its back will be dusted with pollen. When it visits another flower, the back of the body comes in contact with the stigma and pollination is effected.

In the flowers of orchids we have a most perfect mechanism for securing cross-pollination although it is very complicated. The flowers of the orchid *Habenaria platyphylla* are visited by moths in the dusk both morning and evening. These flowers are pure white and are in racemes. In the flower there are three broad sepals, three

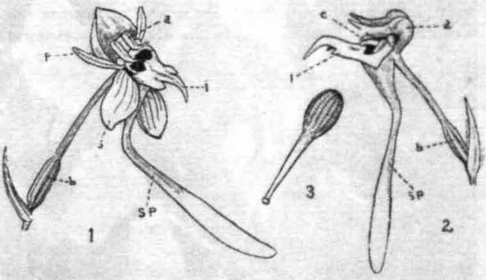


Fig. 114.—Floral parts in the flower of *Habenaria platyphylla*. 1, whole flower; 2, flower without the calyx and corolla; 3, pollinium; s, sepal; p, petal; a, anther; b, ovary; c, stigma; s p, spur; l, labellum.

petals of which two are narrow and the third modified into a lip with a long hollow spur at its back. The two lateral petals and the sepal lying above are together so as to form a hood. There is a narrow passage leading into the interior of the flower, and the anther is situated on a column just above the passage leading into the spur. The pollen-grains in this flower are collected

together into two masses called the **pollinia**. Eacl pollinium has a long stalk whose basal portion protrude: a little. When the moth visits the flower and tries t drink the honev in the spur, the pollinia stick on to the head of the insect and when it flies to another flower th pollinia are rubbed against the stigma lying below th anthers and the pollen masses adhere to the stigma as its surface is sticky.

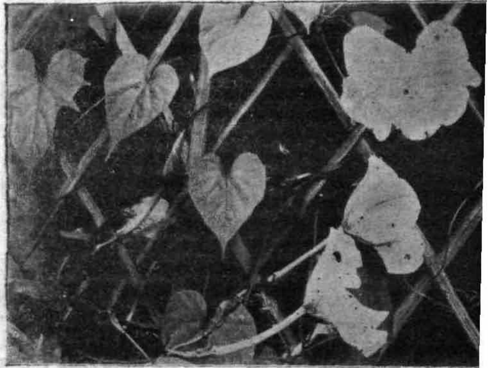


Fig. 115.—Flowers of *Ipomoea bona-nox*.

We have many plants in which the flowers are poll nated by moths. As moths move about only in the dus flowers they visit have white corollas. For example, tl flowers of *Ipomoea bona-nox* or the moon-flower a white and tubular with its limb spread out and regula Further, these flowers give out a strong scent in th

dusk of the evening. The flowers of *Mirabilis* and *Jasminum* are also pollinated by moths. In all these flowers the anthers are generally loose and are well adopted to shed the pollen on to the body of the hovering moth. The hawk-moths *Herse convolvuli* and *Cephonodes picus* visit the flowers of many of the large-flowered species of *Ipomoea*, and *Mirabilis jalapa*. The former is a very constant visitor, but the latter one comes occasionally and it is extremely active and its motions are very rapid.

Submerged water plants depend for their pollination on water. Plants such as, *Ottelia alismoides*, *Hydrilla verticillata*, and *Vallisneria spiralis* have their flowers pollinated on the surface of the water in which they live. Most of these species of plants have uni-sexual flowers. Both the staminate and the pistillate flowers develop under water, and at the time of flowering the staminate flowers get separated from their stalks and rise to the surface and float on water. Staminate flowers are formed in large numbers. The stalks of the pistillate flowers elongate so that the stigmas may be just on the surface of the water. The male flowers floating about on water come near the stigmas by the movement of water and pollination is effected.

CHAPTER X

FRUIT AND SEED

A FRUIT is the ripened ovary or the gynaeceum. Since the variation in the gynaeceum of the flower is very great, we should naturally expect a great variety of development in the fruit also. Although the immediate object of fertilisation is the formation of the embryo with its food, it also induces the development of the various parts of the ovule. In other words, seeds are formed as the result of fertilisation. The influence of fertilisation often extends to the other parts of the gynaeceum and the flower. As a rule, changes occur in form, structure and size in the carpels, placentas and seeds, *but other parts also are occasionally subject to* changes. For instance, the thalamus grows in various ways and becomes incorporated with the carpels as in strawberry, rose and guava. We have also fruits formed from whole inflorescences, as in pine-apple, jack fruit and mulberry. All these changes, whether in the gynaeceum, ovary or other parts in the flower, are intended to afford protection to the seeds and be of use in dispersion. In some plants, especially those under cultivation, such as *Musa* and orange, the ovary developes into the so-called fruits even without fertilisation, and it is interesting to note that seeds are not formed in them.

From a morphological point of view, the fruit is not a new thing. We find in it only those parts that were in existence in the gynaeceum, but considerably altered in size and structure. For instance, before fertilisation the ovary is very small in *Cucurbita* and coconut and after

fertilisation it developes into a big fruit in both these plants. The changes taking place are only physiological. But if we consider the parts of the ovule we find in it after fertilisation something new, namely, the embryo and the endosperm.

From what is said above it is obvious that the nature of the fruit depends upon the nature of the gynaeceum to a certain extent. If the gynaeceum is apocarpous, the fruit also is apocarpous. The gynaeceums in *Ranunculus*, *Michelia* and *Polyalthia* are apocarpous and so are their fruits. Each of these free carpels in the fruit is considered to be a fruit. The pericarp is dry in *Michelia* and *Ranunculus*, bursting open in the former and not at all opening in the latter. In *Polyalthia* the pericarp is fleshy and so the carpels do not dehisce. A syncarpous ovary results in a syncarpous fruit and its carpels are consolidated into a single body. As examples we may mention the fruits of *Argemone*, *Sida* and *Abutilon*.

Fruits may be classified in many ways. A fruit formed from a single flower, and consisting of a single carpel or many carpels, all united and consolidated into one, is termed a simple fruit. If the fruit possesses more than one carpel and all free and developed from a single flower, it is called an **aggregate** fruit.

When the fruit is formed from an inflorescence it is called a **multiple** or **composite** fruit.

Generally fruits enclose one or more seeds, and in the simplest case it consists of seeds and pericarp only. In many fruits the pericarp remains fleshy and succulent, while it becomes dry in others. So fruits are also grouped into dry and fleshy fruits. It must, however, be remembered that this separation is purely artificial because in nature there is no sharp distinction between dry and fleshy fruits.

Dry fruits:—Dry fruits may consist of a single carpe or many carpels, free or united. If there are many seed in the fruit it bursts open, and it does not do so if ther is only one seed. In syncarpous fruit the carpels eithe open at the back and liberate the seeds, or break into a many segments as there are carpels. Fruits havin many seeds in them must of necessity dehisce, if not al the seeds will germinate in close proximity to on another and the seedlings suffer on account of keer competition. Single-seeded fruits do not dehisce, anc the seeds are set free ultimately by the decay of th pericarps. So dry fruits are either indehiscent or dehiscent.

The fruits of *Ranunculus*, *Naravelia* and *Clematis* are apocarpous and each of the free carpels contain single seeds and are indehiscent. Such fruits as these are termed **achenes**. The inferior fruits of sun-flower and other plants of the family Compositae are one-seeded and indehiscent. So they are also achenes. In achenes the seed-coats merely lie in close contact with the pericarp and there is no fusion. There are also single-seeded fruits in which the pericarp fuses with the seed-coat. This is so in the fruits of cereal plants and grasses, and such fruits are termed **caryopsis** or **grain**. Sometimes an achene-like indehiscent fruit becomes winged and, then, it is called a **samara**. The fruits of *Ailanthus excelsa*, *Hardwickia binata* and *Pterolobium indicum* are samaras. In some fruits the pericarp becomes hard and woody forming a shell, as

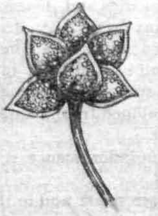


FIG. 116.—Achenes of *Ranunculus*.

in Oak and Beech. These fruits are called **nuts**. Coconut *is a near approach to a nut, but the shell is only the* inner portion of the pericarp.

There are many-seeded dry fruits which generally split into a number of one-seeded parts resembling achenes. The fruits of *Pavonia, Leucas*, castor and *Sida* are of this nature. The *fruit breaks into as many* segments as there are carpels. Such fruits as these are termed **schizocarps** and the individual segments **cocci**. As stated above *the coccus* is indehiscent in *Leucas, Pavonia* and *Sida*, but some times they also dehisce as in *Ricinus*.

Fig. 117.—Schizocarp of *Pavonia zeylanica* 1, coccus or a segment; 2, fruit; 3, fruit with cocci separated.

Fruits of *Calotropis gigantea, Vinca rosea, Wrightia tinctoria* and *Sterculia foetida* are apocarpous fruits and their individual carpels dehisce to shed their seeds. These fruits open by *only one* suture, the ventral suture which bears the seeds and are called **follicles**. The fruit developing from a mono-carpellary pistil such as those of *Crotalaria verrucosa, Caesalpinia pulcherrima* and *Tephrosia purpurea* open along *both the sutures, namely*, ventral and dorsal. These fruits are called **legumes**. Most of the plants of the family Leguminosae have this

kind of fruit, namely, legume. In some Leguminous plants the fruit splits transversely into one-seeded pieces. This kind of fruit is termed a **lomentum**. Fruits of several species of *Desmodium* and of *Mimosa pudica* are lomenta.

A syncarpous many-seeded dry fruit is usually dehiscent, and it is called a **capsule**. It may consist of two or more carpels, and it may be unilocular or multilocular. The fruits of many of the plants of the family

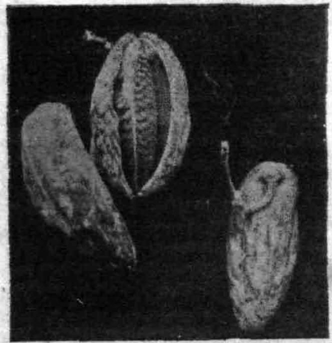


Fig. 118.—Follicle of *Calotropis gigantea*.

Cruciferae are bicarpellary fruits with a false partition dividing the locule into two cavities. There are two parietal placentas and the walls of the loculi break away from the false septum and the placentas, from below upwards. This kind of fruit is called the **siliqua**. A unilocular capsule with parietal placentas may have only

ores at the top of the fruit, or may open by valves to berate the seeds. The fruit of *Papaver* possesses pores t the top of the capsule and seeds escape through them. n the fruit of *Argemone* we find valves only at the top, but not extending to more than about one fourth of the length of the fruit. The fruit of *Ionidium* splits down to the base into three valves, and in this case each valve represents the halves of two contiguous carpels and is placentiferous in the middle. In *Portulaca* the capsule opens by a transverse-lid and this kind of fruit is called a **pyxidium.**

Fig. 119. Follicle of *Wrightia tinctoria.*

Usually multilocular capsules with axile placentation open longitudinally either along the back of the carpels between the partition walls of the locules, as in *Hibiscus esculentus*, or they dehisce along the lines of the junction of the carpels, splitting each of the septa into parallel plates and separating the carpels from one another. The former mode of dehiscence is called the **loculicidal** and the latter **septicidal**. In loculicidal dehiscence seeds are exposed immediately after dehiscence, whilst in septicidal dehiscence each separated carpel has to dehisce along the ventral suture to liberate the seeds. Further, the segments of the capsule after dehiscence correspond to the carpels, in septicidal dehiscence, but

those resulting from loculicidal dehiscence do not correspond to them. Each segment consists of one half of each of the two contiguous carpels. In some capsular fruits the pericarps break away from the septa, leaving

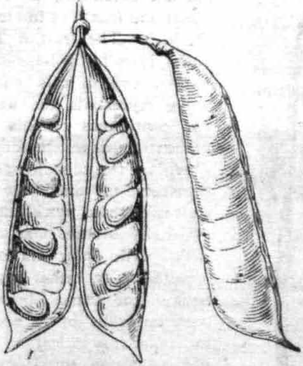


Fig. 120.—Legume of *Caesalpinia sepiaria.*

them as a column in the centre. Then the dehiscence is **septifragal**. According to the position of the septa with reference to the pieces of the pericarp we may distinguish two kinds of septifragal dehiscence. When the septa are exactly opposite to the middle of the pieces of the pericarp it is **loculicidally septifragal**, and if the septa are opposite the opening it is **septicidally septifragal**.

Fleshy fruits.—We have a large number of fruits which are succulent even when they are ripe and ready

o fall off from the parent plant. These fruits contain everal seeds and they escape by the gradual decay of he pericarp, when it is fleshy or after it becomes dry.

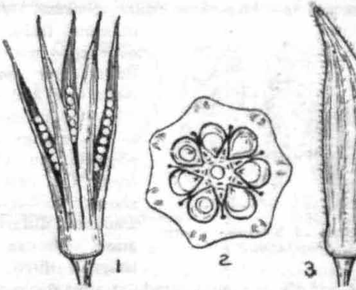


Fig. 121.—Capsule of *Hibiscus esculentus*. 1, dry fruit burst open; 2, transverse section of green fruit; 3, green fruit.

The fruits of grape-vine, guava, *Solanum* and tomatoes, mango, almond, pears and apples are fleshy. The pericarp in guava, grape, tomato, and in the fruits of *Solanum* is fleshy and succulent through out its thickness and when ripe the fruit becomes pulpy. In the fruits of *Solanum* and in guava the pulpiness is due to the pericarp and the placentas becoming fleshy. In tomatoes the pulp is contributed by the pericarp, placentas and seed-coats. All fruits in which the

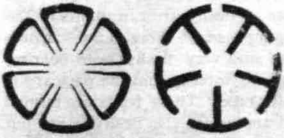


Fig. 122.—Diagram of septicidal and loculicidal dehiscence.

whole of the pericarp is more or less succulent and not hardened are called **berries**. Generally berries have many seeds, but we have also one-seeded berries such as the date and the chow-chow fruit. (*Sechium edule.*)

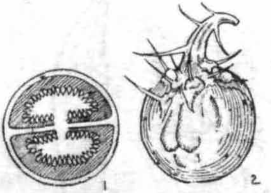


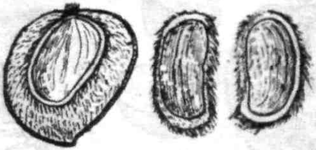
Fig. 123.—Berry of *Solanum*. 1, berry cut across; 2, full berry.

In some fruits the pericarp is not very fleshy but somewhat firm and leathery in consistency, as in orange and pompelo. In these fruits the pericarp shows a certain amount of differentiation. We can distinguish three distinct parts, namely, the outer glandular aromatic portion or the epicarp, the somewhat whitish spongy portion or the mesocarp and the inner portion or the endocarp covered with water-cells which extend to the seeds. Fruits of this kind are called **hesperidiums**. In some fruits the pericarp is fleshy at one stage and later on it dries up as in *Capsicum*.

We have another kind of fleshy fruit in plants of the family Cucurbitaceae composed of three to five carpels forming a single cavity with very fleshy seed-bearing placentas. These fruits are inferior and the pericarp is united to the receptacular tube. These fruits are termed **pepos**. The pears and apples are also fleshy fruits, but the fleshy part is only the thalamus. The pericarp forming the five cells is hard, parchment-like and united externally to the receptacular tube. This kind of fruit is called a **pome**.

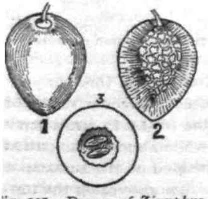
Some fruits have pericarps fleshy outside and hard

d stony inside, as in mango and *Zizyphus* fruits. ch a fruit is a **drupe**. In drupes the epicarp is thin d membranous, the mesocarp is fleshy and the endo-rp becomes a hard shell. The coconut is also a kind



g. 124.—Drupe of Mango. 1, longitudinal section of mango; 2 and 3, portions of the hard endocarp.

drupe. The green or brownish external part is the ›icarp, the middle fibrous part is the mesocarp and the ıell is the endocarp. The kernel is really a seed consting of a hollow endosperm filled with water. In mango there is a single seed and it is enclosed by the shell, and in *Zizyphus* the shell encloses two seeds. But in some plants, as in *Vitex* the seeds are enclosed by separate bits of shells, instead of being enclosed by one shell. These are really **druplets** and are sometimes called **pyrenes**.



'ig. 125.—Drupe of *Zizyphus*. 1, Entire fruit; 2, longitudinal section of the fruit showing the hard endocarp; 3, transverse section of the fruit.

There are also instances of fruits in which the fleshy part does not belong to any ›art of the fruit proper. For example, the fleshy portion n the cashew-nut, though called a fruit, is only the

pedicel become fleshy. So this is a false fruit. The real fruit is the nut at the free end of the peduncle.

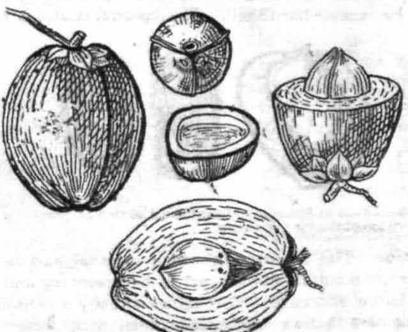


Fig. 126.—Coconut. 1, entire fruit; 2, transverse section of fruit showing a portion of the nut; 3, longitudinal section showing the nut; 4 and 5, views of nut:

As already stated in the earlier part of this chapter, other portions besides the gynaeceum become modified and form part of what is called the fruit. In strawberry the fleshy part is the thalamus swollen and the so-called seeds are all small carpels imbedded on the surface of the fleshy thalamus. In *Nelumbium speciosum* the top-shaped fruit is really the thalamus expanded and the so-called seeds are really ripe carpels embedded on the top of the thalamus.

We have already said that an apocarpous fruit developed from a single flower is termed an **aggregate** fruit. The fruits of *Ranunculus, Clematis, Naravelia* are

regate fruits consisting of indehiscent dry carpels or enes. The aggregate fruit of *Michelia Champaca* and ts of many Asclepiadeae have dehiscing carpels ich we have called follicles. In the fruits of Raspberry

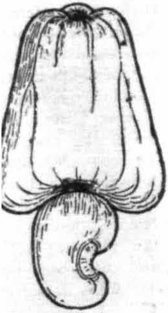


Fig. 127.—Cashew-nut.

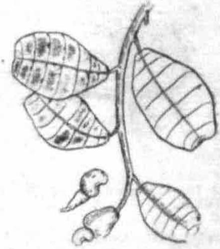


Fig. 128.—Branch of Cashew-nut with fruit.

d *Polyalthia* the carpels are fleshy, and they are upelets in the former and berries in the latter.

We have lastly to consider **composite** or **multiple** iits formed from the development of the whole of the florescence. In *Dorstenia indica* the fruits are very iall and they are imbedded in a flat disk, which is ally the receptacle. This is called a **coenanthium.** In veral species of *Ficus* what is called the fruit or fig merely the hollow receptacle bearing unisexual flowers, side on its surface. This is termed a **fig, syconium** or **panthodium.**

The fruits of jack and pine-apple are also inflores-nces in which the rachis of the inflorescence and parts

of the flowers have become fleshy. In the jack flow are unisexual and so the spikes are either of male flow or female flowers. It is the female spike that develop into the composite fruit called the jack-fruit. The edib flakes in this a really the fema flowers, the succule sweet portion bein the perianth and th membranous bag er closing the see being the pericarp The coarse filament between the flake are undevelope female flowers. I the pine-apple th

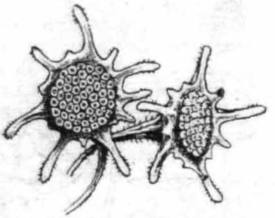


Fig. 129.—Coenanthium of *Dorstenia indica*.

fleshy part consists of the rachis and the lower portions of the flowers. The polygonal areas appearing

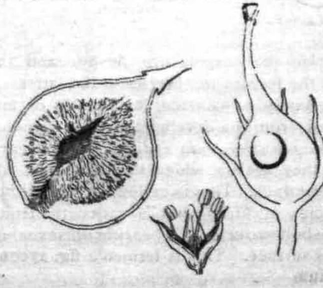


Fig. 130—Fig or syconium.

externally correspond to the flowers and in them the

mains of bracts and other parts of flowers are often sible.

The ovule developes into the seed soon after fertili-tion. In the seed we recognise all the parts of the ule, only they are considerably modified. The seed-ats, testa and tegmen are derived respectively from the outer and the inner integu-ments. The cells of the outer integument are thin-walled, but when it changes into the testa, the cell walls become thickened by suberisation and lignification, because it has to serve as an effectives organ against drying and injury for the young plant. In some seeds, as in mustard and lin-seed, the epidermis of the seed-coat becomes mucilaginous, and this helps in retaining water and also serves as a means of fixation to the soil. Seeds of Acanthaceous plants have hairs growing out from the epidermal layers and these also are mucilaginous and help in fixation to the soil. In the seed-coat, we also find the micropyle, the hilum, and raphe in anatropous seeds. All these are parts present in the ovule even before fertilisation.

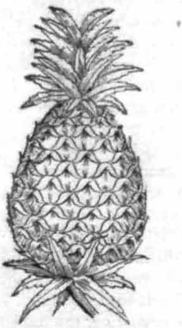


Fig. 131.—Pine-apple.

The embryo and the endosperm that are formed within the embryo-sac as the result of fertilisation are really newly formed parts. In all seeds endosperm is formed and it persists within the embryo-sac in some seeds and in others it disappears with the growth of the embryo. Those seeds in which the endosperm persits are called

endospermous seeds, and seeds in which they do n persist are **non-endospermic** seeds. In the case of no endospermic seeds the endosperm gets absorbed l the embryo, and finally the cotyledons become larg on account of the transfer of material from the endc perm to the cotyledons. This transfer of material fro the endosperm to the cotyledons becomes obvious if v examine the seeds of some leguminous plants in tl course of development. In partially developed seeds *Dolichos*, *Crotalaria* aud *Caesalpinia* we find the sma cotyledons embedded in a fleshy mass which is vei massive in very young seeds, and it gradually decreas and the cotyledons increase in size proportionately the seed grows.

As a rule, the nucellus tissue gradually decreases the embryo and the endosperm are developed withi the embryo-sac, and finally wh the embryo is fully formed tl whole of it disappears. But, ho ever, in a few seeds, such as tho of *Piper*, *Nymphaea*, *Canna* ar *Elettaria Cardamomum*, the nucell tissue persists and we find it occ pying considerable space withi the seed between the seed-coat ar the embryo-sac. This nucellus tiss in the seed is called the **perisper** and seeds having it perispermic seeds.

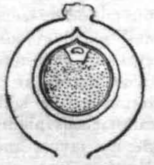


Fig. 132.—L. Section of the fruit of *Piper nigrum*.

Seeds also show variations. They are multifarious i their form i.e., they may be round, oval, flat, cylindr cal and angular. The seed-coat may be smooth, wrinkle furrowed, ribbed, tubercled or reticulate. It may ha hairs or wings as outgrowths. In the seeds of Asclepi deae hairs occur as a tuft at the pointed end. Such seed

are called **comose** seeds. In some seeds, as in those of *Alstonia*, tufts of hairs are found at both the ends of the seed. Hairs are found all over the surface of seeds in *Hibiscus micranthus*, *Cochlospermum gossypium* and in *Eriodendron anfractuosum*. In some seeds, such as those of *Dolichandrone*, *Tecoma*, *Oroxylum* and *Cedrela*, outgrowths take the form of wings. In many a seed the testa is hard and shell-like, especially where protection is not afforded. If the seeds are well protected by a hard pericarp, the seed-coats remain thin. In some seeds even the seed-coat is not present, as in *Crinum* seeds.

Fig. 133.—Comose seeds of *Calotropis*.

Sometimes we find outgrowths merely covering the seeds without adhering to the seed-coats. Such outgrowths usually arise from the funicle or from the micropyle and they are called **arils**. In the seeds of *Nymphaea* and in those belonging to the family Passifloreae the arils grow out from the funicle, and they are micropylar in origin in *Myristica* and *Inga dulcis*. If the outgrowth is small as in the seeds of *Polygala* it is called a **strophiole**. In castor seed it is termed **caruncle**.

In the embryo the primary axis is well differentiated into the plumule and the radicle in many seeds, and in some seeds even leaves can be seen in the plumule. This differentiation is not patent in a few seeds. The cotyledons may be thick or thin and leaf-like.

The two cotyledons may be similar and equal or they may be unequal, as in *Artocarpus integrifolia* and *Hopea parviflora*. We find the cotyledons irregularly

lobed in the seeds of *Vateria indica*. In monocotyle donous seeds there is only one cotyledon and it i clearly distinguishable in many seeds. In some seeds i is not distinguishable. For instance, in the coconut date seed and in the seeds of some other palms th embryo is usually small and cylindric without an differentiation. But as germination progresses, the cotyle don (or haustoria of some authors) developes, grows an

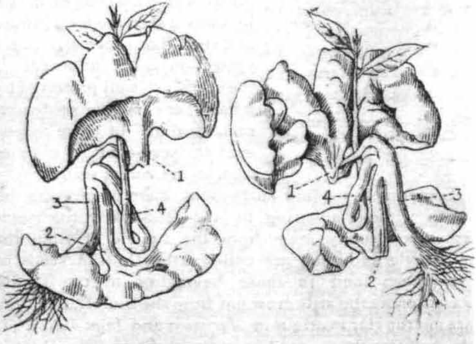


Fig. 134.—Lobed cotyledons of *Vateria indica*. 1 and 2, cotyledons 3, hypocotyl; and 4, plumule developing into shoot.

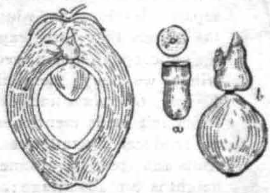
absorbs the endosperm, by filling up the whole of th cavity. This enlarged cotyledon is often spoken of as "the apple."

In a few plants the seeds are enclosed permanently and they do not come out of the pericarp or other enve lopes even when they germinate. All such fruits are one-seeded. The caryopsis of cereal plants and grasses

nd achenes are of this nature. In some seed-like fruits he external covering is the lower portion of the erianth. This is the case in the so called "seeds" of *Iirabilis, Pisonia* and *Boerhaavia.*

Dispersal of fruits and seeds.

Flowering plants have a tendency to produce as nany seeds as possible. This production of seeds in arge numbers is an absolute necessity, as otherwise the



ig. 135.—Embryos of Coconut in different stages of development. 1, Longitudinal section of coconut showing the developing young plant in position; 2, embryo before germination; 3, young plant detached.

naintenance of the average number both as regards the ndividuals and the species becomes impossible. Furher, these seeds should also get distributed far and vide. Most of the special features that are seen in ruits and seeds are useful in helping the distribution of eeds. If all the seeds that are produced by a plant were o fall beneath the tree or near it and germinate there, a een struggle is sure to occur and the individuals that nay be expected to survive are indeed few. Even with ll the facilities for dispersal a large number of the eeds may fall on barren ground and hence the producion of seeds in abundance becomes necessary.

The agents concerned in the distribution of seeds ar currents of air, water and animals including man.

Fruits and seeds provided with wings or plumes ar specially adapted for dispersal by wind, because the offer a large amount of surface. Th fruits of *Gyrocarpus*, *Hopea*, *Holop telea*, *Pterocarpus*, *Pterolobium*, *Hard wickia*, *Fraxinus*, *Ailanthus* and *Com bretum* are winged. In the first tw sepals develop as wings and i the others they are expansions o the pericarp. Amongst seeds that hav wings we may mention those o *Tecoma*, *Oroxylum* and *Cedrela*. Th fruits and seeds mentioned above ar all produced by tall trees. As thes fruits and seeds have some weight th height is an advantage; the curren of wind is stronger above than below However, it should not be though that waftage by wind of fruits an seeds is confined to trees alone. Even low plants hav fruits and seeds with adaptations for dispersal. For inst ance, the achenes of most of the Compositae are provide with pappus hairs. Considering the low position of th herbs, the parachute-like pappus hairs of the fruits o *Tridax* and several other plants of the family Composita are far more efficient for their dispersal than wings The seeds of many species of the family Asclepiadea are provided with tufts of hairs (coma), growing from near the micropyle at the narrow end. Plants of thes two families have a very wide distribution, on account o these special adaptations in their fruits and seeds fo dispersal.

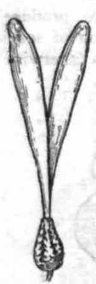
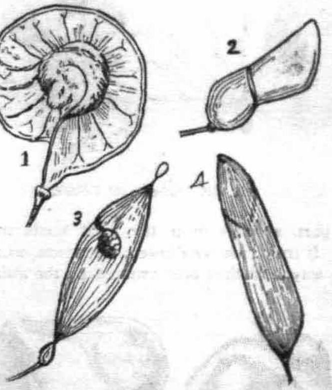


Fig. 136.—Winged fruit of *Gyrocarpus*.

In many plants the seeds are very minute in size and so very light. This of course renders the seeds most itable for dispersal by wind. Many of the epiphytic chids are able to thrive well in moist tropical forests,



g. 137.—Winged fruits. 1, *Pterocarpus*; 2, *Pterolobium*; 3, *Ailanthus*; 4, *Hardwickia*.

ecause of their seeds being minute and light. Seeds of me orchids have also a loose reticulate testa with enty of air inside.

Animals also serve as agents in the distribution of eds. Fleshy fruits are meant to bring about the stribution of seeds by means of animals. Animals

deliberately go in search of fleshy fruits and devour them. As already pointed out fleshy fruits have either seeds with hard testa or they are covered by hard endocarps, as in drupes and pyrenes. After eating the

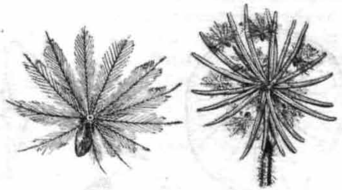


Fig. 138.—Achenes of *Tridax*.

fleshy part, animals drop the hard seeds in various places. If fruits are swallowed, the seeds do not suffer in any way and they are avoided by the animals. In

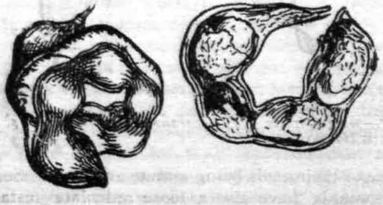
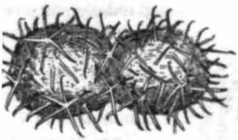


Fig. 139.—Arillate seeds of *Pithecolobium*.

several instances passage of the seeds through the digestive tract of animals assists the seeds in

nature so as to be attractive to animals. In unripe s seeds would be in an immature condition, and so do not become differentiated in colour from the ge leaves. This mode of distribution is very common

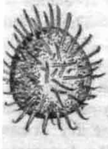


ig. 140.—Hooked fruits of *Pupalia*.

Fig. 141.—Hooked fruit of *Xanthium*.

it ranks very high among the different modes of ersal, and is second only to dispersion by wind.

me seeds have arils which cover the seeds and make attractive. Birds secure these seeds for the sake of eating the edible arils and then they drop the seeds in different places.



42.—Hooked fruit *Triumfetta*.

Hooks, spines and sticky glands are other devices in some fruits to make them cling to the bodies of animals roaming amongst herbs and shrubs. If we examine our clothing after a walk through a waste place overgrown with weeds, we find many kinds of fruits sticking to clothing. Fruits of the plants *Pupalia*, *Desmodium*, *yranthes*, *Triumfetta*, *Aristida*, *Tragus* and *Boerhaavia* hooks, spines or sticky glands. The hooks in the

fruits of *Desmodium* and *Triumfetta* are developed from the pericarp. In *Pupalia* imperfect flowers develop into hooks. The tips of the perianth are the parts that stick on in *Achyranthes*.

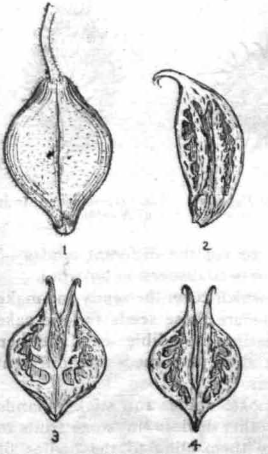


Fig. 143.—Fruits of *Martynia diandra*. 1, Entire fruit 2, 3 and 4 with the endocarp only and curved stiff hooks.

In the case of the fruits of *Boerhaavia* glandular stalks are borne by the persistent portion of the perianth. Hooks develop from bracts in *Xanthium* and *Tragus*.

The drupes of *Martynia diandra* are very innocent looking when succulent. But very soon the fleshy outer part dries up leaving the hard black endocarp well exposed with two stiff curved hooks at the free end of the fruit. These hooked spines cling on to the body of animals and at this stage the fruit is very easily detached.

Some dry fruits, especially legumes, get dispersed by their bursting, and the valves becoming twisted. Seeds are hurled to some distance in this case. The schizocarps of *Ricinus* also behave similarly. As the pericarp of the fruits dries, they suddenly burst and the seeds are scattered.

Water also is helpful in the matter of dispersal of seeds. Fruits such as those of *Cerbera Odollam*, Lotus and *Entada scandens* are carried to distant places by waves of water. Ocean currents play a great part in the distribution of fruits and seeds.

The distribution of food and other economic plants is entirely the work of man. So far as these plants are concerned distribution is brought about by man deliberately and consciously. He is also responsible for unintentional distribution of several weeds which, though not indigenous to the local flora, have established themselves firmly in this country. The conspicuous weed *Tridax procumbens* is an introduction into this country and within a few years it has spread all over the place in South India and has even gone up to higher altitudes to about 4000 feet. Other weeds of recent introduction are *Flaveria australasica*, and *Acanthospermum hispidulum*. Another weed *Alternanthera echinata* with prostrate habit of the family Amarantaceae is now fast spreading all over Bangalore city and Coimbatore. This is evidently a very recent introduction, because four or five years ago this plant could not be seen any where in these cities. The Amarantaceous plant *Gomphrena decumbens*, now found as a bad weed everywhere in the city of Madras was not seen sixteen years ago. These two introduced weeds are figured under Amarantaceae.

CHAPTER XI

'LANT CELL, TISSUES AND TISSUE SYSTEMS

ALL plants begin their lives as a small bit of proto-lasm, and it is called a cell. In the case of Spermato-hytes we have seen that this cell results from the fusion f two cells from two distinct sources. By repeated ivision this single cell becomes a mass of cells consti-ıting the embryo. So long as the embryo is dormant nd within the seed, it consists of cells more or less omogeneous. Soon after germination the embryo egins to grow and increase in size. This growth and ıcrease in size are brought about by further formation of ells by division and their transformation; and these two rocesses *go on incessantly in a plant so long as it is* live. Thus we see that the cells are the structural units elementary organs of plants.

The term cell is not at all appropriate and it is mis-ading. When Robert Hooke examined a piece of ork tissue under the microscope in the year 1667, he ompared the structural units of cork to the "cells of a oney comb" and used the term cell for the first time to enote the cell wall and the cavity enclosed by it. The rotoplasm, the essential part of the cell, was not recog-ised till about the middle of the last century. Our esent knowledge of the structural details of proto-asm is mainly derived from the researches of Schlei-en, Robert Brown, Hugo Von Mohl, F. Cohen and . Strasburgher. The nucleus was discovered by R. rown, and the semi-transparent viscous substance und inside the cell was first recognised as the physical asis of life and named protoplasm by Von Mohl.

By an examination of a thin longitudinal section of the growing point of a root or stem we can learn the constituent parts of a cell. When such a section is examined under the high power of the microscope, it is

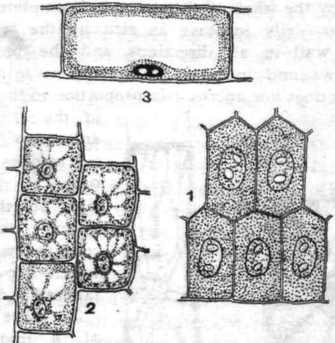


Fig. 144.—Embryonic cells (somewhat diagrammatic.) 1. Meristem cells; 2. young cells with many small vacuoles; 3. an old cell with one large vacuole.

seen to be made up of a large number of rectangular cells which are separated from one another by very delicate **cell walls.** All the cells are full of protoplasm which is very dense. In every one of these cells lies a large oval or spherical body occupying a fairly large part of the cavity. This is the **nucleus** of the cell. The space between the cell wall and the nucleus is occupied by a finely granular substance and it is termed **cytoplasm.** A number of small refractive bodies without any colour are found imbedded in the cytoplasm, and these are called **plastids** or **chromatophores**. The

cytoplasm, nucleus and the plastids constitute the *living contents of the cell.*

A mature cell has also the same parts that are found in the cell at the growing point, but the protoplasm does not occupy the whole of the space and completely. The embryonic cells increase in size by the growth of the cell wall in all directions and the protoplasm also grows and increases in amount up to a certain limit, but does not increase in proportion to the growth of the cell. In the enlarged cells we see cavities or **vacuoles** of different sizes in the cytoplasm; and these contain water in which various substances are dissolved.

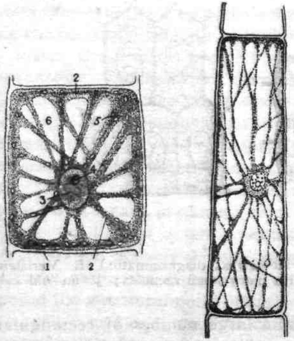


Fig. 145.—Two typical vegetable cells in a mature condition from the hair of *Cucurbita.* 1, cell wall; 2, protoplasmic strand; 3, nucleus; 4, nucleolus; 5, chloroplats; 6, vacuole.

To have an idea of a mature cell showing the protoplasm in a living state, the hairs growing on the sepals of the flower buds of *Cucurbita maxima* may be examined under the microscope. A hair consists of a number of cells and the cell walls are transparent. By confining our attention to a single cell of the hair we can make out all the parts clearly and learn a great deal about the behaviour of protoplasm in a living cell. The cell is bounded externally by a distinct cell wall of

uniform thickness. The walls separating the cells under observation from the cells above and below sometimes show shallow pits. Each protoplast is thus completely enclosed by an elastic membrane or cell wall, which consists mostly of cellulose. A thin layer of cytoplasm is in contact with the cell wall at all points and encloses a large internal cavity or vacuole which is filled with a watery cell sap. The nucleus which is highly refringent lies suspended in the centre of the cell by means of a large number of threads and strands of cytoplasm running from it to the film of cytoplasm lining the cell wall. The nucleus is always surrounded by a sheath of protoplasm. In other words, whatever position the nucleus may occupy in the cell we find it always embedded in the cytoplasm. The cytoplasmic threads traversing the cell cavity may show branching. Crystals and plastids are often found imbedded in the cytoplasmic strands and in the layer lining the cell wall. In a fully mature cell we find only the cytoplasmic layer lining the cell wall with a large single vacuole filled with cell sap. The nucleus in this case occupies a parietal position in the peripheral cytoplasmic layer.

Fig. 146.—Cells of the staminal hair of *Cyanotis.*

Protoplasm in the living cell is viscous and semi-liquid. It behaves as a liquid. Although enclosed in a cell wall the cytoplasm frequently shows movements, as may be seen in the cells of the hairs of *Cucurbita.* Both the layer lining the cell wall and the strands traversing the cavity show the streaming movement. Within the

same cell the movement will be in one direction in some strands and in others in the opposite direction. Occasionally in the same strand streaming movement in opposite directions may occur. This streaming movement is called **circulation** The staminal hairs of *Cyanotis* also show circulation very well. The protoplasm in the cells of some plants, especially in those of aquatic plants, show movements of a different kind, called **rotation**. Rotation occurs only in cells in which the cytoplasm is reduced to a layer lining the wall and enclosing a large continuous vacuole. The cells of the leaves of *Vallisneria* are particularly good for the study of rotation in protoplasm. The movement is only in one direction and it follows the cell wall. In a cell the direction of the movement may be left to right and, in the cell next to it, it may be in the reverse direction.

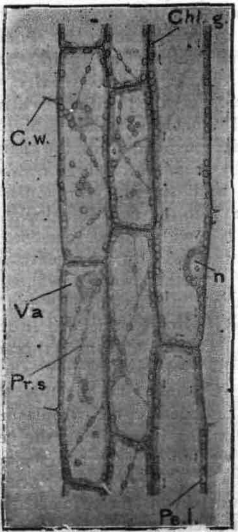


Fig. 147.—Cells of the leaf of *Villisneria spiralis*., Chlg., chloro plasts; C.w, cell wall; n, nucleus; Va, vacuole; Pr.s, protoplasmic strands; Pe.l, peripheral layer of protoplasm.

Protoplasm is capable of perceiving different kinds of stimuli and responding to them in a suitable manner. This power of the protoplasm is called irritability. All

the processes connected with the nutrition of the plant and reproduction are initiated and carried out by protoplasm. In short the specific nature of the entire plant is dependent on the control exercised by the protoplasm.

A very large portion of protoplasm in the living condition is water. Protoplasm consists of highly complicated unstable substances which are subject to continual changes. Proteins form the largest part of it. When in the living condition protoplasm is alkaline or neutral in reaction, but never acid. In the living protoplasm a large number of proteins and several other organic substances occur. This substance is actually alive only within a narrow range of temperature. At temperatures above 50° C it becomes coagulated. Acids and alcohol also cause it to coagulate.

Cytoplasm.—In general appearance cytoplasm is alveolar. When highly magnified we can distinguish in it a clear hyaline external layer which is very narrow, free from granules and an inner granular layer. This peripheral boundary layer and a similar clear hyaline layer bounding the vacuole are very important parts of the protoplast, as the passage of substances is determined by them. Further, this clear plasmatic layer is renewed whenever it is injured. Cytoplasm is really made up of a large number of very minute granules and droplets not visible under the ordinary microscope, but visible when examined with the ultra-microscope. Since protoplasm consists of minute ultra microscopic particles it is considered to be a colloidal solution. This conception of the protoplasm helps to explain many a vital process on a physico-chemical basis.

Since protoplasm is enclosed by the cell wall it may be thought that a cell is isolated and not connected with the other cells around it. But there is sufficient evidence

to conclude that all the cells of living tissues are in intimate relation to one another. It is now established beyond doubt that in the mature tissues of at least some plants there is continuity of protoplasm from cell to cell. Extremely fine filaments of protoplasm pass from the boundary layer of the protoplasm of a cell to the similar layers of protoplasm in the surrounding cells, either through the entire thickness of the cell wall or through the pit membrane. On account of these connecting filaments of protoplasm the whole of the plant body becomes an organic unit. This connection of protoplasm with that of its neighbouring cells by means of fine filaments can be seen in thin section of the endosperm of date seed, if treated with sulphuric acid and chloro-zinc iodine, or methylene blue.

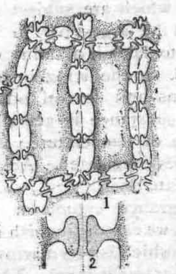


Fig. 148.—Cells in the endosperm of a date seed. 1, cells with pits; 2, a pit highly magnified to show the fine filaments of protoplasm.

The nucleus.—It is now an established fact that for the maintenance of the protoplast in a living condition nucleus is necessary. As it performs certain special functions, it should be considered as an organ of the protoplast. In the cells at the growing points the nuclei may be about half the diameter of the cell and it is spherical. In older cells they are oval or lenticular. In size it becomes smaller with the increase of the cell in its volume. To make out the structural details of the nucleus protoplasm must be killed and stained with special reagents.

In the living cell the nucleus has a finely dotted

appearance, but when stained, it is seen to consist of a net work of **chromatin** or a substance taking a deep stain and consisting mainly of proteins containing phosphorus. In the living condition the nucleus appears to be a kind of fluid like the cytoplasm and surrounded by a nuclear membrane by which the cytoplasm is separated from the nuclear cavity. Within the nucleus a small compact body is found and it is called the **nucleolus**; sometimes two nucleoli may be seen. The interstices of the net-work are filled with nuclear sap. In the nucleus the *most important part* is the reticulum consisting of threads that do not get *stained deeply. But some granular substance imbedded* in these threads becomes stained deeply. The threads are called **linin** threads and the granular substance that stains deeply is called **chromatin.**

The part played by the nucleus in the growth and nutrition of cells is not inconsiderable. If protoplasm is injured, it is only the part which contains the nucleus that is able to repair the injury, and the portion without it is incapable of this process and consequently it is decomposed. It is the nucleus that initiates cell-division and it is this body that bears the hereditary characters which are transmitted to other individuals.

Plastids.—These bodies are very small and so they cannot be easily seen in young embryonic cells. But as cells mature they become larger and increase in number by division. In the cells forming part of the vegetative region, such as leaves and young tender stems, they become green and then they are called **chlorophyll corpuscles** or **chloroplasts.** The green colour of the leaves is due to the presence of chloroplasts in them in myriads. In all higher plants these bodies are ellipsoidal or some what spherical, although they assume various

shapes in Algae. The framework of the chloroplast is a colourless matrix of specialised protoplasm. The green colour is due to the presence of four pigments, two green, one red and the other yellow. The green pigments are called chlorophyll *a* and *b*, the red *carotin* and the yellow *xanthophyll*. The chloroplasts in young fruits are at first green and, as the fruits mature, they become red and orange and then these bodies are called **chromoplasts**. In petals and flowers colourless plastids change into chromoplasts. In tubers and other parts of plants inaccessible to light the plastids remain colourless and develop into bodies called **leucoplasts**. They are useful in changing sugar into starch and *vice versa*. On exposure to light leucoplasts change into chloroplasts. Plastids being specialised parts of protoplasm, they are derived only from pre-existing bodies, and cannot arise *de novo*.

The cell wall.—The cell wall is derived from the protoplasm. Naked protoplasm very soon forms this membrane at its periphery. In embryonic cells the cell walls are very thin and difficult to see. As the cells grow in length and in breadth the cell wall must necessarily increase in length and breadth. Until the cells attain their usual size the cell wall grows only in surface and so it remains thin. The increase in the surface in the cell wall is brought about by the introduction of new particles between those already existing. The cell walls of cells in certain parts of plants are thick and this thickness is due to the laying down of new layers one above the other by the activity of protoplasm. This process of thickening goes on on both sides of the partition wall of two adjoining cells and the newly formed layers are not so refractive as the original cell wall. So the original cell

wall stands out clearly in the middle with the new layers on both the sides. This layer being in the middle, it is spoken of as the **middle lamella**. The cell walls of cells found in the hard portions of the plant such as wood etc., show the thickening as well as the middle lamella very well. When the thickening is very great as in sclerenchyma, striations are clearly visible in the cell wall on both sides of the middle lamella. The thickening of the cell wall is never uniform. While some portions are thickened, other portions are not. The variations in the thickening of cell wall is dealt with in another connection.

Non-living substances found in the cell.—All vital activities characterising plants are initiated in the cell and, therefore, we may legitimately expect many substances to be found in the protoplasm. In the vacuoles of protoplasm there is always water in which many substances may exist in solution. Insoluble substances also may exist in the protoplasm.

The cell sap is acid in reaction. The various colours such as red, pink, blue and violet in the petals are due to substances dissolved in the cell sap. Many kinds of salts and sugars may also be in the cell sap.

The insoluble substances may be in the form of very minute particles or drops and these appear as granules, or as refractive bodies. Some of the substances may accumulate in fairly large masses and possess certain definite characteristics, by which we recognise them. Such large bodies usually found within the cells of plants are aleurone grains, crystals, starch grains and fat or oil.

Crystals of calcium oxalate are found in the cells of many plants. In the cells in which these crystals are found the protoplasm disappears, and the cell serves as

a storehouse for the crystal. The crystal may be a simple crystal having a cubic, rhomboidal or prismatic form, or it may be a compound crystal consisting of several simple crystals. In some plants these crystals exist as needle-shaped ones aggregated in bundles. These kinds of crystals are called **raphides**. In some plants, especially in those of the family Urticaceae calcium carbonate occurs as a pear shaped body projecting into the cell-cavity. This is termed a **cystolith** At first a small protuberance of cellulose arises on the cell wall internally, and it gets impregnated with calcium carbonate as it grows larger.

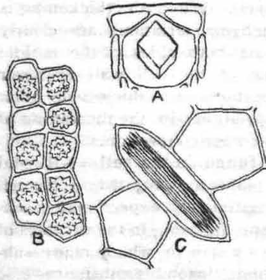


Fig. 149.—Crystals occurring in cells. A, simple crystal; B, compound crystals; C, raphides.

Aleurone grains.—These are proteid grains occurring usually in the cells of endosperm or cotyledons of oil seeds. In the endosperm of *Ricinus* seed these grains are well-developed and lie embedded in the cytoplasm An aleurone grain of *Ricinus* is ellipsoidal in form and it encloses a crystal of albumen and a globoid of double phosphate of calcium and magnesium. These grains also occur, without any inclusions, as small bodies in the cotyledons of many seeds. They are particularly abundant in the peripheral layers of grains of cereal plants. Aleurone grains are abundant in the seed

of *Amygdalus, Helianthus* and other oil containing seeds.

Starch grains.—Most of the living cells in the stem and roots of plants abound in starch grains. In tubers, rhizomes and seeds starch grains are abundant and they are large in size. They vary very much and most of them show striations. All the starch is really formed within the chloroplast imbedded in the cytoplasm, and the starch grains thus formed are very minute. All the starch thus formed is transported to other parts, in a soluble state, and there again they are deposited as large grains. Leucoplasts are the agents in building up these large starch grains.

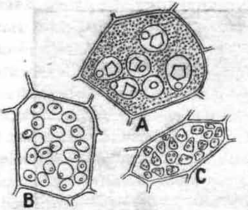


Fig. 150. Aleurone grains of A, *Ricinus*. B, *Carthamus* and C, *Sesamum*.

Indirect division of the nucleus or Mitosis.—All the cells and their modifications found in a plant are derived from the single cell in the embryo-sac, which is formed as the result of fertilisation. So it follows that every cell arises from a pre-existing cell. All the constituent parts of the cell, namely, plastids, nucleus and cytoplasm arise by division of the pre-existing plastids, nucleus and cytoplasm respectively. None of the living constituents of a cell is known to be formed *de novo*, but like the plant itself, they are the descendants of progenitors of like nature.

Cell division is always going on in the cells at the growing points. When a cell is about to divide we notice

certain changes in the nucleus of that cell, because it is the nucleus that initiates the process. The resting nucleus which is delimited from the cytoplasm by the nuclear membrane, consists of a delicate network whose inter-

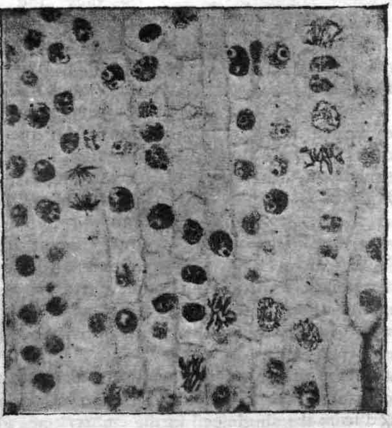


Fig. 151.—Cells in a longitudinal section of a root of *Tradescantia* showing division of nucleus and the chromosomes.
Note the anaphase stage of the chromosomes in the third row and the metaphase stage of the same in the other rows of cells.

stices are filled with nuclear sap. When the nucleus is about to divide its fine network becomes irregular and coarse. In its place are found a number of bodies with irregular outlines. These bodies soon resolve themselves into a definite number of short, thick and dense threads or filaments. These filaments are called **chromosomes** on account of their taking a deeper stain

than other parts of the cell. These chromosomes become more prominent and each of them undergoes a longitudinal split. After the splitting they move into a plane about the middle of the cell. Here the chromosomes, which are split longitudinally, aggregate to form what is called the equatorial plate. At this stage the chromosomes are U-shaped with their bends towards the interior of the cell and their open arms towards the outside. The changes occurring from the beginning of the breaking up of the fine network to the splitting up of the chromosomes are termed the **prophase** of cell division. The next stage **metaphase** is the stage in which the chromosomes form the equatorial plate.

Simultaneously with the initiation of changes in the nucleus, the cytoplasm also undergoes certain changes. In the cytoplasm fine fibrils are differentiated near the nucleus and these arrange themselves in two opposed groups. All the fibrils of a side converge to a point on that side further from the nuclear cavity, and the point is called a pole. As soon as the filaments arrange themselves into two groups one on each side of the cell, the nucleoli and the nuclear membrane disappear and the filaments grow longer going towards the nuclear cavity and become continuous. The chromosomes at the equatorial plate become attached to these filaments now called the nuclear spindle.

The chromosomes as already stated split longitudinally and arrange themselves in the future plane of division so as to form the equatorial plate. The number of chromosomes occurring in the cells of any species of plant is as a rule constant. For instance, in *Canna* there are six chromosomes, in *Marsilia* thirty-two, in *Nymphaea* sixty-four or ninety-six and in *Nephrolium* one hundred and twenty-eight. In the nucleus of *Canna*

there are six chromosomes, so at the metaphase of cell division there would be twelve chromosomes at the equatorial plate.

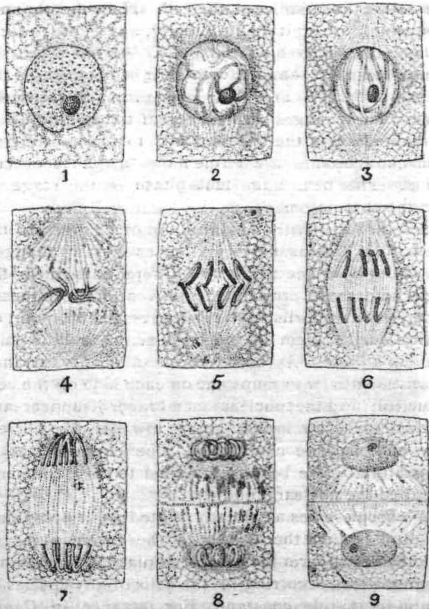


Fig. 152.—Diagram of indirect nuclear division or mitosis. 1-3, prophase; 4, metaphase; 5-7, anaphase; 8-9 telephase.

The two halves of each chromosome lying at the equatorial plate move in opposite directions until the

daughter chromosomes reach the farther ends of the cell or poles. The stages from the separation to the reaching of the farther ends by these chromosomes constitute the **anaphase**. Further changes until the formation of the two daughter nuclei are spoken of as **telephase**. After reaching the poles these chromosomes crowd together to form two nuclei. Each of these two nuclei gets surrounded by a nuclear membrane formed from the cytoplasm. The chromosomes next change into a delicate network and nucleoli appear within this network. At the equatorial plane the cytoplasm forms a wall thus dividing the cell into two daughter cells.

From the elaborate changes occurring during cell division, it is obvious that this process is intended to bring about an equal distribution of the substance of the nucleus to the two daughter nuclei at each division. Further, we see that the individuality of the chromosomes is maintained. There is absolutely no material change in the quality of the nuclei inasmuch as an equal share of the substance of each chromosome passes to each of the two nuclei. When cells multiply in this manner, each and every cell must have exactly the characters of the parent plant. In other words, each constituent nucleus will bear the full heritable qualities of the parent.

The complicated processes involved in mitotic division afford enough evidence to hold the view that chromosomes are the bearers of hereditary characters. As a result of mitotic division, each daughter nucleus receives a set of chromosomes exactly similar to one another and resembling the mother nucleus in every respect. The chromosomes are thus carefully divided and perpetuated without alteration.

Reduction division or **Meiosis** :—Another kind of cell division occurs in the mother-cells of pollen grains and

spores, and it is termed **reduction division or meiosis.** The cells of anthers, ovules, and sporangia of cryptogams undergo division in the usual manner, until the formation of the mother-cells of the pollen-grains or

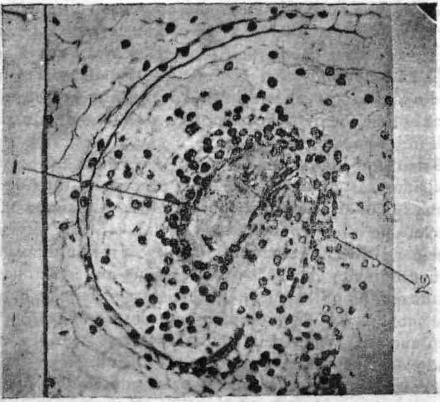
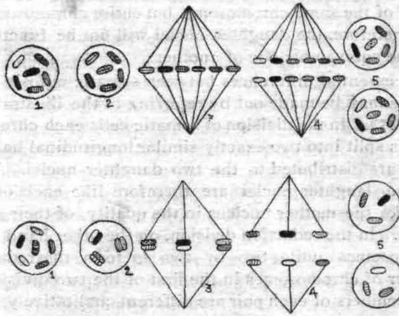


Fig. 153.—Division of the nucleus in the embryo-sac of the ovule of a Lily. 1, embryo-sac; 2, a nucleus in which the chromosomes are in the metaphase stage.

spores. The mother-cell undergoes division twice before it gives rise to the four pollen-grains or spores. During the first division the nucleus of the mother-cell breaks up into chromosomes and they arrange themselves at the equatorial plate as they do in the case of mitosis or indirect nuclear division. *But the number of chromosomes* at the equatorial plate in the case of pollen or spore mother-cells will be exactly the same as the number of

ıromosomes in the somatic or vegetative cells, and not ouble the number, as is the case in ordinary indirect ivision of cells. If in a plant the number of chro-osomes in the somatic cells be six, during indirect ivision there will be twelve chromosomes at the



ɡ. 154.—A diagrammatic representation of somatic and reduction livision; the upper figure represents the stage of mitotic or somatic cell division and the lower figure is meiosis or reduction division.

uatorial plate i.e. double the number, and each daughter ll receives six of them. But in the division of the ollen mother-cell the number of chromosomes at the uatorial plane will be only six and each daughter cell ould, therefore, consist of only three of them. Further, e *chromosomes at the equatorial plate in meiosis are* ot longitudinal halves of chromosomes, but full chromo-mes which separate from one another.

Each of the chromosomes formed after the breaking of the network represent a pair of chromosomes in hich both paternal and maternal chromosomes become sociated. Consequently the number of chromosomes

that are to occupy the equatorial plate is just half as many as those found in the vegetative cells of the same plant. *Soon after reaching the equatorial plane, separation* of the chromosomes takes place. In this separation of chromosomes, the chromosomes do not represent halves of the same chromosome, but entire chromosomes, and, therefore, the daughter nuclei will not be functionally the equivalents one of another.

The essential differences between somatic mitosis and meiosis may be made out by referring to the illustration in fig. 154. In the division of somatic cells each chromosome is split into two exactly similar longitudinal halves which are distributed to the two daughter nuclei. The the two daughter nuclei are therefore like each other and like the mother nucleus in the quality of their substance. In the reduction division, on the other hand, the chromosomes unite two by two to form the reduced number of chromosomes in the first of the two divisions. *The members of each pair are different qualitatively.* So when they separate and pass to the two new daughter nuclei, they must necessarily be unlike in quality because of having different members of the full chromosome group. They will also be not like the mother nucleus, since each of them possesses only half as many chromosomes as the latter.

After the first division, each of the daughter cells with only half the number of chromosomes that are found in the somatic cells again divides, the division this time being essentially like mitosis. As a result of these two divisions four nuclei are formed and the four cells with these nuclei are of two kinds.

The pollen-grains and spores contain only half the number of chromosomes found in the somatic cells of the plant. The reduction in the number of chromosomes

:curs during the first division of the mother-cells. For iis reason this mode of cell division has been termed **eduction division**. The cells of the plant body are alled **diploid** because of the full number of chromo-›mes and the pollen-grains and spores **haploid** as they ›ntain only half the number of chromosomes.

TISSUES AND TISSUE-SYSTEMS

Among plants it is only the lowest forms of life living ı water that possess a simple type of structure. The ›dy is either unicellular or multicellular. Some of the west forms of plants are unicellular, and they remain › throughout their life. In such plants all the vital ınctions are performed by the single cell. The plant ›dy of even a lower multicellular plant consists of a ımber of protoplasts separated by cell walls. All the :lls in the plant body are more or less similar in struc-ıre and function. In other words, we find similar cells ggregated together and this aggregation of cells is sually spoken of as a **tissue**.

As we ascend from the lower to the higher plants we ›tice a gradual increase not only in the size of the plant ›dy but also in external organisation. The parts be-›me more complex, numerous, and they have to perform fferent functions. All the external modifications result om the changes occurring in the cells. The groups of :lls constituting the plant body acquire diversity in ›rm, structure and function. In the higher plants the :lls, although more or less uniform when they arise, :come segregated into variously constructed kinds of :lls, connected by intermediate forms. Hence it is that e find in the organs of plants similar cells associated gether in groups, which constitute different kinds of ssues. These tissues may be considerable in amount ıd be found in unbroken connection extending for some

distance only, or they may be connecte throughout the plant body. The tissues are distinguished from one another by the form, contents, and the walls of their constituent cellular elements.

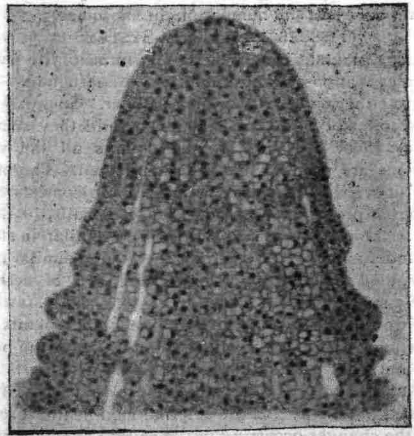


Fig. 155.—A longitudinal section of the growing point of the stem of *Hippuris*.

From the study of the various organs of flowering plants we learn that they are made up of different kinds of tissues, and that the kinds of tissues are definite and limited in number. The tissues of plants fall into two primary classes, namely, the **formative** or **meristematic** tissues and the **mature** or **permanent** tissues.

I. Formative or **meristem** tissues.—We know that

the embryo or the young plant within the seed consists of cells all more less uniform in structure and form and that all these cells are derived from a single cell by cell division. These cells form a kind of tissue called

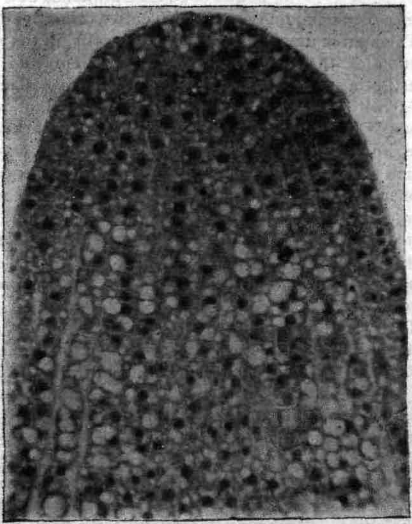


Fig. 156.—A longitudinal section of the growing point of the stem of *Hippuris*. (Highly magnified) Note the large nuclei of the cells.

meristem tissue. When the embryo grows into a seedling after germination, differentiation of cells into tissues commences, but the meristematic cells become lo-

calised at the tips of leafy branches and roots. However diverse may be the form and structure of the various elements that make up the tissues of vascular plants, they are all derived from the embryonic cells located at the tips or growing points of foliage branches and roots. Hence meristematic tissue is also called formative tissue.

The aggregate of actively dividing cells, in the apical portion of the vegetative cones of stem and roots constituting the meristem tissue, consists of small cubical cells with very delicate cell walls, abundant dense protoplasm without vacuoles and a very large nucleus. The growing point, the young leaves and lateral branches which arise from the embryonic part of the apex consist of meristematic tissue. The apical meristem is continually carried forward by the enlargement of the cells beneath it that have been formed by its own activity, just as a man standing on a brick-wall which he is constructing is pushed upwards with each successive layer of bricks.

The vegetative cone of the plumule produces at its apex rudiments of leaves and lateral branches on its sides, and these appear at first as small protuberances. As activity increases in the cells below the meristematic apex, these rudiments of lateral branches get separated and, when leaves, nodes and internodes become differentiated, the rudimentary lateral branches still existing as groups of meristem cells occupy the axils of leaves. Thus it is obvious that all the meristems found at the apices of growing points of all the branches of a plant owe their origin to the meristem of the growing point of the seedling of the plant. So all the meristems found at the growing points are **primary.**

In the cells lying below the meristematic cells a certain amount of change becomes apparent. They grow differ-

ently and give rise to strands or layers of variously shaped formative cells, which at first retain the general characteristics of meristem cells.

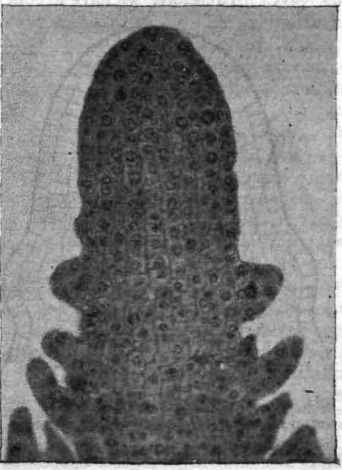


Fig. 157.—A longitudinal section of the growing point of the stem of *Elodea*.

It is possible to distinguish in the vegetative cones of at least some plants three distinct regions, namely, **dermatogen**, **periblem** and **plerome**. Dermatogen is the outermost layer of cells covering the vegetative cone, the developing leaves and buds. The cells of this layer continue to divide only by walls at right angles to the

surface. In other words, division takes place only b anticlinal walls. If this layer is followed downwards will be found to be continuous with the epidermis c stem and leaves. Therefore, we have to conclude tha

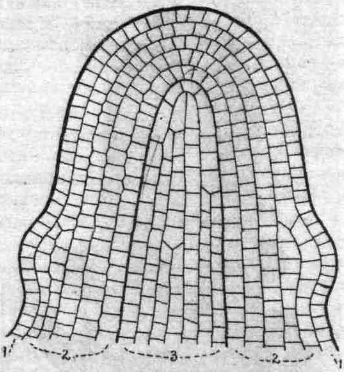
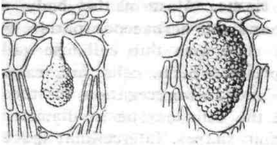


Fig. 158.—A-diagram of a longitudinal section of the growing poi of the stem of *Hippuris*. 1, dermatogen; 2, periblem; 3, plerom

dermatogen is epidermis in the embryonic stage. In al plants in which the epidermis is one-layered it increase in superficial expanse to keep pace with the increase i the tissues within. The central cylinder of the vegetativ cone is called the **plerome** and the layers of cells lyin between the dermatogen and the plerome constitute th **periblem.** A sharp distinction between the periblen and the plerome exists only in certain plants, while i others it does not exist. In certain plants the distinctio becomes apparent lower down. The periblem give

ise to the cortex including the endodermis and the stele s derived from the plerome.



'ig. 159.—Crystals of calcium carbonate (cystoliths) occurring in the epidermal cells of the leaf of *Ficus*.

Besides the vegetative cone there are other parts also in a plant in which meristem tissue is found. The layers of cells which cause the secondary *thickening* in stems and roots of dicotyledonous plants and hose which produce cork constitute meristems. But these neristems differ from the meristem at the growing oint in one important respect. While the apical neristem of the vegetative cone is derived directly rom pre-existing meristem, the cambium of secondary hickening and cork-cambium are formed from cells hat have ceased to divide and become permanent arenchymatous cells. On account of this difference ambium must be termed **secondary meristem.** The ambial cells, however, differ from the cells of the rimary meristem in shape. These cells are usually longated or flattened prisms.

II. Permanent tissues.—All cells and tissues other ıan meristem come under this head. Permanent ssues consist of cells that are larger with freely acuolated protoplasm. In some cases the cells become ead losing the protoplasm. The cell walls are variously ıickened and also chemically altered.

Tissues or tissue-systems included under permanent ssues are the following:—

1. Parenchymatous tissue, 2. Epidermal tissue, Cork tissue, 4. Mechanical tissues, 5. Vascular

tissues, 6. Laticiferous tissues and 7. Glandular tissues.

1. **Parenchymatous tissue.**—Most of the body of of a herbaceous plant and the herbaceous parts of a woody plant consist of cells with thin cellulose walls and vacuolated protoplasm. Such cells are called **parenchymatous** cells, and an aggregation of these **parenchyma**. In shape the cells may be iso-diametric, or elongated and of various shapes. Intercellular spaces occur in parenchyma. The cytoplasm may contain chloroplasts or leucoplasts according to the position the cells occupy in the plant. As the cells of this tissue are living cells, they serve a variety of functions. They carry on the most important vital processes occurring in plants, namely, preparation, conduction and storage of nutritive materials, storage of water and respiration. They also contribute towards mechanical strength, as they maintain their turgidity. Parenchyma in which the cells are abundantly provided with chloroplasts, as in leaves, is often spoken of as **chlorenchyma**. When numerous large intercellular spaces are found in parenchyma it is termed **aerenchyma**.

2. **Epidermal tissue.**—The epidermis is the outermost layer of cells covering the exterior of the plant body, especially the leaves and all the herbaceous portions. As already stated this is derived from the dermatogen, and it forms an excellent protective tissue against loss of water, parasitic fungi and mechanical injury. In many plants the epidermis is the only protective tissue existing in herbaceous plants and in herbaceous parts of woody perennials. In the vast majority of plants the epidermis consists of only one layer of tabular or more or less elongated cells without intercellular spaces between them. The lateral walls of the epidermal cells are undulating

So long as these cells are alive they contain protoplasm which is generally reduced to a very thin layer with the vacuoles filled with coloured or colourless cell sap. Except in ferns and in some shade-loving plants, chloroplasts do not occur in the epidermal cells. Very often the epidermal cells serve as water-reservoirs. The many-layered epidermis occurring in *Nerium* and *Ficus* are efficient water reservoirs. In the epidermal cells of many species of *Ficus* crystals of calcium carbonate or cystoliths are commonly found. This has already been referred to on page 178.

The outer walls of the epidermal cells which last for a considerable time are usually thickened. This thickening is caused by the apposition of cellulose layers the outer of which usually becomes more or less cutinised. In addition to this thickening, sometimes a continuous cutinised film, called the **cuticle**, is found covering the outer walls of these cells.

In some plants wax may be found deposited on the cutinised layers of the epidermis. The so-called bloom on the stems, leaves, and fruits is due to the deposit of wax. In consequence of the deposits of wax water will flow off the epidermis without wetting it. The covering of wax may be in the form of grains, small rods or crusts. Occasionally the walls of epidermal cells are infiltrated with silica, as in some Gramineae. By this deposition the mechanical strength of the outer walls is increased. In equisetums the silicification is very great and the pericarp of *Coix lachryma-jobi* is as hard as opal.

The cuticle and cuticularised layers are almost impermeable to water and gases. Therefore, the outer walls of the epidermal cells bearing cuticularised layers and cuticle prevent the loss of water by evaporation. In

xerophytes the cuticle as well as cutinised layers are very prominent in the epidermis.

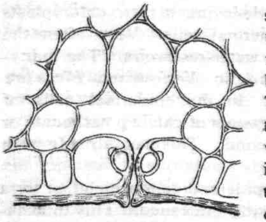


Fig. 160.—Epidermis of Aloe leaf, showing cuticle and stomatal apparatus.

In spite of the cutinisation and thickening of the epidermis, comparatively speaking, it is to be considered only thin. Therefore, it may be thought ill adapted to withstand mechanical injury. But considering the fact that epidermal cells are small and that the radial walls are very numerous and close, any mechanical impact will be borne by the radial walls very effectively. Furthermore, the outer walls of the epidermal cells generally curve outward and this also is advantageous. When the outer wall is silicified the walls become more resistant.

The continuity of the epidermis is interrupted here and there by the **stomatal apparatus**. Stomata are found in large numbers on the green parts of plants, and especially in the leaves. A stoma is an intercellular passage or pore with a pair of half-moon-shaped cells, one on each side, called **guard cells**. Generally the lower epidermis of leaves contain the largest number of stomata. Some leaves have them on only one side and in others they may be found on both the sides. The largest stomata occur in grasses. In wheat the pore itself is said to vary from 0.007 mm to 0.038 mm. the stomata measure 0.079 in length and 0.039 mm. in breadth. In a square millimeter of space stomata average from 100 to 300. As examples of leaves having

stomata on both sides we may mention *Cucurbita Pepo* and grasses. The lower epidermis in the leaves of *Cucurbita* have about 270 stomata in a square millimeter, and on the upper epidermis they average about 30 to a square millimeter. In the leaves of grasses both the sides contain very nearly the same number of stomata. At any rate, there is not very great difference. In the leaf of *Zea* the lower surface has 68 per sq. mm. and the upper 52. The stomata are mainly useful in the matter of exchange of gases.

The epidermis very often bears on its surface outgrowths of various kinds. The simplest outgrowth is the hair, which is merely a prolongation of the outer wall of the epidermal cells. This is either unicellular or multicellular. In young buds of some plants numerous long hairs form a more or less thick coating, which protect the buds against a too rapid evaporation of water. Some plants have glandular hairs, others branched or stellate hairs. Occasionally the hairs get infiltrated with carbonate of lime or silica and become stiff bristles. Stinging hairs and scales also occur in the epidermis of some plants. In some plants prickles also are found, but they are not derived solely from the epidermis. A portion of the sub-epidermal tissue also takes part in their formation.

3. **Cork tissue** :——From its very nature the epidermis cannot be expected to become a permanent protective membrane, although it is known to persist for a number of years in some species of *Viscum* and *Acer*. When the epidermis is no longer living and functionally not active, the tissues are protected even more efficiently by suberised cells or cork tissue.

While the epidermis is always a primary permanent tissue, the cork is always a secondary tissue, and is

developed from a secondary meristem, formed in the cells of the cortex, either superficially or deeply. Some of the parenchymatous cells of the cortex begin to divide and this forms the secondary meristem known as **cork-cambium or phellogen.** An initial layer is always present in the cork-cambium.

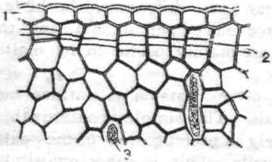


Fig. 161.—Formation of cork in a very young stem of *Jatropha*. 1, Epidermis; 2, phellogen; 3, latex-tube.

As a rule, the initial layer of cork-cambium gives rise to cork cells externally. In some plants it also produces cells internally, thus adding to the cortex some more layers of cells. These new layers form the **phelloderm** or secondary cortex.

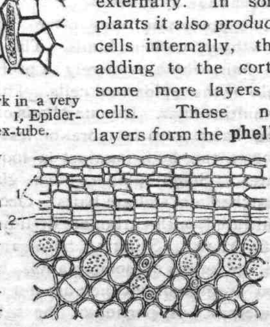


Fig. 162.—Formation of cork in an old stem of *Jatropha*. 1. cork cells; 2, phellogen.

Cork begins to form only after a certain amount of secondary thickening has taken place. The appearance of brown colour in stems is an indication of the formation of cork. Cork forms where the epidermis has been thrown off, or where living parenchyma has been exposed by wounds.

When fully developed cork consists of rows of cells forming closely packed tiers without intercellular spaces. Cork cells have a flattened prismatic form with thin walls. In the cell wall the middle lamella is lignified and the superficial layers alone are suberised. Although

very thin, the cell walls of cork cells are impervious to both air and moisture. As cork tissue is many-layered, it is more efficient as a protective membrane than epidermis, both against loss of water and mechanical injury. Air being a bad conductor, the cork tissue which consists of cells with plenty of air in them protects the inner tissues against injuries that might result from sudden changes in temperature.

Lenticels:—The cork tissue is a continuous layer, except where lenticels occur. Lenticels are formed simultaneously with the cork tissue. On stems they appear as slightly swollen, round, oval or narrowly elliptical spots or excrescences, and when seen under a lens a lenticel appears as a narrow slit, filled in with some powdery tissue.

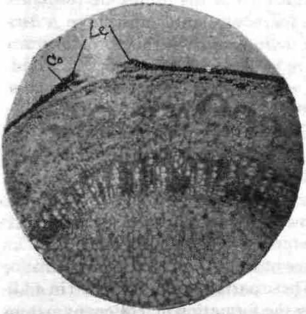


Fig. 163.—*Transverse section of the stem of Odina* showing a lenticel cut through. Co, cork; Le, lenticel.

Like cork, lenticels also are formed from phellogen. They almost always develop directly under the stomata. The cells formed in the case of a lenticel do not all resemble the cork cells. These cells are more or less rounded and lie loosely with intercellular spaces. In fact a lenticel is nothing but a group of loose cells. As new cells are formed regularly from the phellogen at the base of the lenticels, they remain for years and may grow to a large size. Besides the loose cells there

are also found sometimes intermediate bands, shutting off the loose cells from the layers below. These closing layers also ultimately get ruptured. The cell walls of the loose cells are not usually suberised, although the cells of the closing bands are suberised or lignified. The phellogen of the cork and that of lenticels join laterally and become continuous.

Lenticels are obviously intended to facilitate the ingress and egress of gases. How this is rendered possible will be explained later.

4. **Mechanical tissues**:—For the proper performance of their functions the parts of plants must have a definite form, and for the maintenance of this form turgidity caused by the presence of water in the tissues is essential. But, however, water alone cannot be depended upon for conferring the necessary rigidity, since it may be lost by evaporation. As a compensation for this, special mechanical tissues are developed. They are **collenchyma** and **sclerenchyma**.

Collenchyma:—Parts of flowering plants undergoing *development and growth consist mostly of parenchyma*-tous tissue and, therefore, there would be turgidity on account of the presence of water. Such parts may also be *elongating actively. These parts are strengthened in addi*-tion to the turgidity by the formation of collenchymatous tissue. This tissue is always developed peripherally beneath the epidermis and just below the surface of herbaceous parts, such as mid-ribs of leaves, petioles and young shoots, and it does not occur in other places. At first it consists of a few layers but if goes on increasing with the growth of the stem. It forms a continuous layer in some cases, and in others it exists as isolated strands.

The special characteristic of collenchyma is that it consists of living cells whose walls are greatly thicken-

ed, especially at the corners where the cells meet. Sometimes the thickening is so great, as to completely obliterate the cell cavity. This tissue owes its origin to the parenchymatous cells of the cortex.

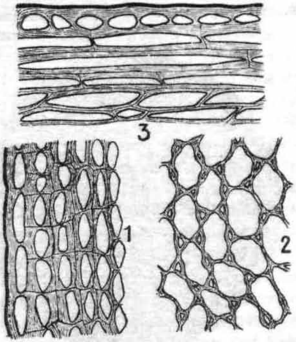


Fig. 164.—Collenchyma. 1, and 2, transverse section; 3, longitudinal section.

The chief function of collenchyma is to give mechanical strength to the parts of the stem still growing. The great thickening of the cells affords the necessary strength, whilst the living contents enable the cells to grow and keep pace with the increase of tissues within.

Sclerenchyma:—Just as collenchyma is the typical mechanical tissue of parts still elongating, sclerenchyma is the mechanical tissue characteristic of fully grown parts of the plant. This tissue is specially intended to give strength to parts that have ceased to grow in length. The constituent elements of this tissue are fibres which are narrow, elongated and spindle-shaped with pointed ends and without protoplasm. In transverse sections they are polygonal. Fibres are dead cells with greatly thickened walls, consisting of layers of carbohydrates which are lignified. The walls may have simple pits. In length these fibres vary, although they average between

1 to 3 mm. In flax they are 30 to 40 mm., about 70 mm. in stinging nettle and 220 mm. in *Boehmeria nivea.*

This tissue is found in the stem either continuously or as isolated strands. In the cortex of several plants it

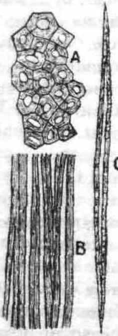


Fig. 165.-Sclerenchyma A, transverse; B, longitudinal section; C, a single fibre in longitudinal section.

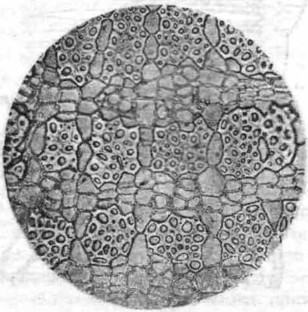


Fig. 166.—Sclerenchyma in the phloem of *Hibiscus cannabinus.*

forms a plexus, or a regular network. It is not unusual to find them alternating with phloem masses. This is the case in most stems of plants of the family Malvaceae.

The vertical elongation, lignification of the walls, the tapering ends and the very close interlacing to form bundles so characteristic of fibres make them not only strong but also elastic. The main use of sclerenchyma is to afford sufficient strength to the members in which it occurs.

Sclerotic cells or stone cells result when cells undergo ickening *without elongating very much.* These are characterised by very great thickening appearing as distinct striations and by the possession of very conspicuous pits, some of them being branched. They occur in the cortex, pericycle, and the pith either singly or in masses. In the hard parts of fruits and seeds they are bundant. In fact the hard parts consist of stone cells.

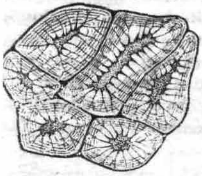


Fig. 167.—Sclerotic cells.

5. **Vascular tissue**:—With the growth of the parts of lants and *increase in their size, the need for rapid* onduction of water and other substances from one art of the plant to another becomes greater. It is ue that a certain amount of diffusion can take place in he parenchyma, but even at its best the movement of vater through this tissue is but slow. Special tissues apable of conducting substances rapidly have therefore risen in higher plants. The main elements of which hese tissues are composed are mostly elongated in the lirection of conduction, and they are in the form of ubes or vessels; hence this tissue is called **vascular** **tissue.** Vascular tissues occur in all parts of the plant and they are connected throughout the plant.

Vessels arise from the *rows of parenchymatous* cells ound at the base of the growing point by fusion. In some of these rows the fusion of superposed cells is not complete. The transverse or oblique septa between the elongated cells become perforated and the cell walls remain thin and they consist of cellulose. The perforated septa are called **sieve-plates** and the vessels or

tubes bearing these plates are called **sieve-tubes.** In *certain other rows the fusion of* the superposed cells is complete, and the transverse septa completely disappear. So the superposed cells become transformed into long vessels or tubes with a continuous cavity. The cell walls also become thickened in various ways. Such vessels as these are called **xylem vessels** or **trachea.** Sometimes single cells become elongated and their cell walls become thickened. Such are called **tracheids.**

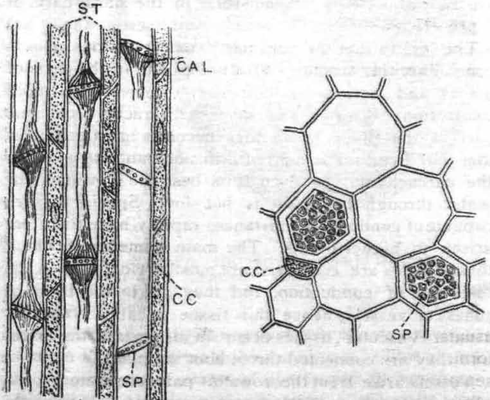


Fig. 168.—Sieve-tubes. The first fig. longitudinal section and the second is a transverse section. S. T, Sieve-tube; C. C, Companion cell; S. P. Sieve-plate.

Sieve-tubes occur in groups mixed up with parenchymatous cells. They form strands running longitudinally

and they are the main channels for the transport of proteins and carbohydrates. Each sieve-tube consists of a row of long cells with sieve-plates. A thin layer of protoplasm is usually found lining the wall and the contents found in the centre of the tube is mucilaginous. Coarse strands of protoplasm pass through the pores of of the sieve-tubes. The walls remain thin and they consist of cellulose only. Each sieve-tube has one or more companion cells connected with it. The companion cells contain protoplasm with a nucleus in it and they are rich in proteins. Hence these are sometimes called "**protein cells.**"

The xylem vessels are the main channels for the conduction of water. The walls of these vessels are

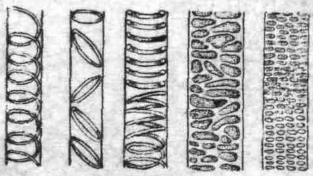


Fig. 169.—Vessels with different kinds of thickenings. 1, and 3, spiral; 2, annular; 4, reticulated; 5, pitted

usually thickened, although the thickening is never uniform. Vessels in which the thickening is in the form of separate rings of lignified substance, set one above the other, are called **annular vessels.** If one or more lignified bands are found running round and round in the vessel through its entire length, it is termed a **spiral vessel.** If the lignified thickened portion is in the form of a network, then the vessel is called a **reticulated vessel.** When the thickening involves the greater part

of the cell wall leaving small areas here and there unthickened, the vessels are called **pitted vessels** and the areas not thickened **pits**. Pits are varied in shape. They may be circular, oval or elliptic. In some vessels the pits are transversely extended and stand one above

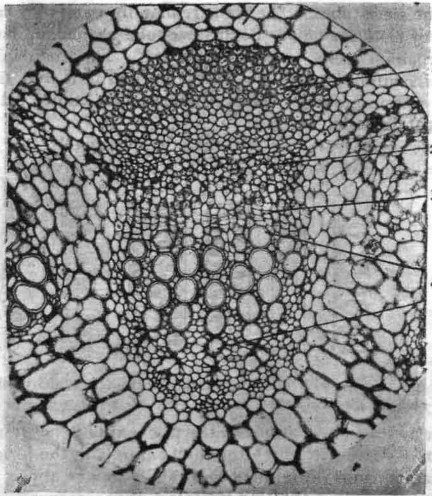


Fig. 170.—An open collateral vascular bundle. 1, sclerenchyma 2. phloem; 3, cambium; 4, xylem.

the other. Such vessels are called **scalariform vessels**. Generally the pits are **bordered** in pitted vessels.

As a rule, both the conducting tissues, namely, sieve-

tubes and xylem vessels or trachea occur as strands or bundles traversing the whole of the plant body. Both these bundles occur together and they are always associated one with the other. Hence these strands or bundles are called **vascular bundles**. At the growing point below the meristematic tissue and in the plerome there arise groups of cells called **procambium** or **procambial strands**. In dicotyledonous stems the inner portion of the procambium is transformed into xylem vessels and from the external part sieve-tube tissue is derived. A small portion of the procambium between

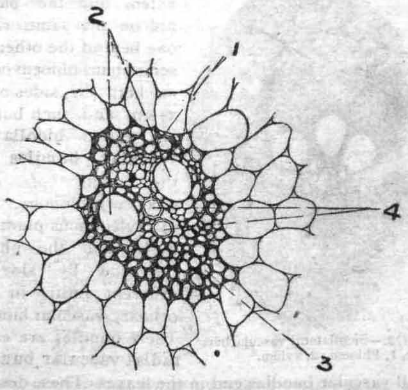


Fig. 171.—A closed vascular bundle. 1, phloem; 2, pitted vessels; 3, sclerenchyma; 4, annular and spiral vessels.

the xylem and the phloem remains without undergoing any change and retaining the power of division. This meristem is *known* as **cambium**. Thus a vascular

bundle in a dicotyledonous plant consists of three parts, namely, the **phloem** or sieve-tube tissue portion, the **cambium** and the **xylem**. A vascular bundle having all these parts is termed an **open vascular bundle**.

In monocotyledonous stems the procambial strands become differentiated into xylem and phloem without any part of it persisting as cambium. The whole of the procambial strand is used up and these bundles are called **closed vascular bundles**. The open bundles of the dicotyledonous stems are called **collateral vascular bundles** because the xylem and the phloem are on the same radius one behind the other. In some stems phloem occurs on both the sides of the xylem and such bundles are called **bicollateral vascular bundles**. In the roots of both monocotyledonous and dicotyledonous plants the xylem and the phloem lie side by side on different radii in the primary vascular bundles. These bundles are called **radial vascular bundles**.

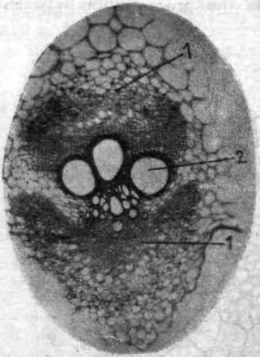


Fig. 172.—Bicollateral vascularbundle, 1, Phloem; 2, xylem.

All vascular bundles end in the leaves. These descend into the stem from each leaf, and after traversing one or more internodes they branch and fuse with the bundles that enter the stem at the lower nodes. So all the vascular bundles of the stem are continuous. The vascular bundles descending into the stem from a leaf form

the leaf trace bundles. All the vascular bundles disposed in the form of a ring in the stems of dicotyledonous plants are composed of leaf trace bundles. As the bundles are common to both the stem and the leaf, they are called common bundles. The upper part of the bundle which runs through the cortex towards the leaf is termed a leaf-trace. Within the stem the vascular bundles run parallel to the axis through the internodes, but at the nodes there is a considerable amount of branching and intercommunication of these bundles.

6. **Laticiferous tissues** :—When we cut the stems or leaves of the plants *Euphorbia*, *Ficus* and *Lactuca*, there is an exudation of milky juice. This milky juice is usually

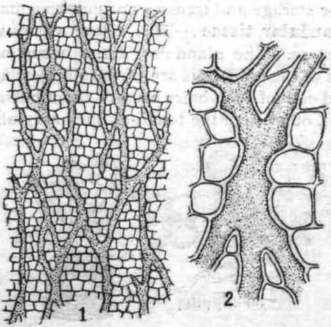


Fig. 173.—Laticiferous system. 1, slightly magnified; 2, highly magnified.

contained in branched cells or in branching and anastomosing vessels. The latex-tubes in *Euphorbia*, Apocynads and Asclepiads are cells developed into branched tubes.

These tubes only branch, but they do not anastomose. On the other hand, the latex vessels in *Lactuca* and *Argemone* are true vessels formed by the fusion of cells. These always anastomose and form networks.

Latex is usually a white milky juice, and it is occasionally colourless or yellowish in colour. This liquid contains gums,resins,caoutchouc, fat and wax in emulsion. In some plants enzymes and poisonous alkaloids are also found in the latex. As these substances are of the nature of excreted products, the tubes are often to be regarded as reservoirs of excreted substances. However, occasionally, starch grains and protein grains occur in the latex. In such cases it is probable that latex-tubes serve for storage and transport of nutritive material.

7. **Glandular tissue** :—This tissue varies very much in structure. The glandular hairs occurring as outgrowths of the epidermis are of the simplest kind. The terminal cell of such hairs usually functions as a gland. But cells, other than the terminal one, may also secrete.

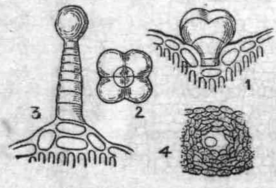


Fig. 174.—Glandular hair and oil glands. 1, side view and 2, top view of a glandular hair of *Ocimum Basilicum*; 3, glandular hair of *Petunia*; 4, oil gland of *Citrus*.

Sometimes a group of cells of the epidermis and subepidermal tissue secrete honey, thus forming a nectary. Generally nectaries are met with in the parts of flowers.

There are also cavities or passages formed in various parts of plants in which ethereal oils, gums and resins are secreted. The oil glands seen in the leaves and in the pericarp of the fruits of lime and orange trees are really cavities formed by the destruction of some of the cells. Such cavities are termed **lysigenous** cavities. Resin ducts or passages also occur in plants and these are formed by the separation of cells first so as to form

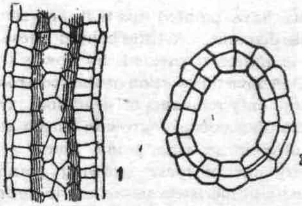


Fig. 175.—Resin ducts. 1, longitudinal; and 2, transverse section.

a slit in the intercellular space and then by further separation it becomes wider. **Resin ducts** occur in the cortex in the stem of *Helianthus*. Such passages as these are called **schizogenous** cavities or passages.

CHAPTER XII

INTERNAL STRUCTURE OF ROOT, STEM AND LEAF

1. Structure of Root

ALL roots have pointed tips that are smooth for a considerable distance. A little behind these ends the roots are completely covered by downy root-hairs. (See fig. 21.) Above this portion of the root, root-hairs are not found and only remnants of dead ones are present. Like the stem the roots also grow in length at their tips by means of their growing points found at their free ends. Every one of these growing points of roots consists mostly of meristem tissue and is protected by a root-cap, as otherwise the meristem is likely to be injured. The root-cap covers the tip of the root as a thimble does the tip of a finger, and its outer cell walls become mucilaginous making the tip move forward easily in the soil. So in a growing point we can easily distinguish three parts, namely, the smooth root-tip, the region of the root-bearing *root-hairs or the root-hair region* and the older portion of the root devoid of root-hairs or the conducting region. All the external features of a growing root can be observed *very easily in a seedling growing* in sand or sawdust.

The smooth root-tip really consists of two distinct regions, namely, the formative region covered by the root-cap and the elongating region. The actual growing point in the formative region consists of equivalent meristematic cells that are arranged in regular rows.

The origin, development and arrangement at the apex of the various layers of cells including the root-cap are very varied. So it is better to select as types the roots of plants whose structure at the tip is simple,

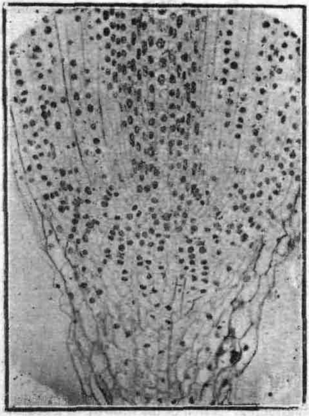


Fig. 176.—Longitudinal section of the root-tip of a *Tradescantia* root.

typical and easy to understand. As an example the root-tip of any grass may be chosen. If a longitudinal section of the root-tip of a grass or any monocotyledon be examined under the microscope, we can clearly distinguish the root-cap, dermatogen, periblem and the plerome. At the apex the root-cap can be made out very distinctly, as it is sharply marked off from the actual root-tip. The plerome is clearly seen in the centre and it

ends in a rounded dome. This is covered by the pe
blem and the dermatogen. These two embryonic regic
end in one single layer of cells intervening between t
root-cap and the dome of the plerome. It is this sin

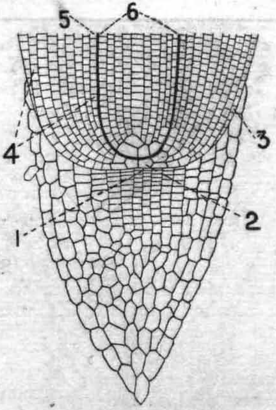


Fig. 177.—Longitudinal section of the root-tip of a grass root (diagr matic). 1, limit of the root-cap; 2, initial calls from which dermatogen and the periblem arise; 3, dermatogen; 4, periblem endodermis; 6, plerome.

layer that gives origin to both periblem and dermatog In monocotyledonous roots we can distinguish at t apex of the root, in properly prepared, truly medi longitudinal sections, three distinct strata, namely, root-cap, the initial layer from which dermatogen a periblem arise, and the plerome. In some dicotyledon root-tips there is a mass of meristem tissue with

ıny strata, from which originate the root-cap, dermatogen, periblem and plerome, while in others the plerome s distinguishable with a single layer of cells intervenng between it and the root-cap. The periblem deveopes from this single layer, and the root-cap and dermaogen have a common origin.

The root-cap is thus seen to arise in the monocotyedonous root from an initial layer just outside the lermatogen, the delimitation between these two being very well marked. In dicotyledonous roots it arises in ;ommon with the dermatogen or from a mass of cells ıt the apex from which the other embryonic strata arise, out none are distinguishable, one from the other, at the extreme apex.

The meristem cells as well as the permanent cells n the course of transformation need oxygen for their growth. So, for the admission of air, air spaces are forned between the cells. At first the cells get separated ıt the angles their walls make with each other. These mall spaces become united so that intercellular passages un among the cells of every region, and they are of lifferent dimensions in different areas. These interellular passages become open to the exterior in the ıpper portion of the plant. This enables the air to nter and circulate through the interior of the tissues. The openings existing in the bark, namely, lenticels acilitate the entrance of air.

As already stated, root-hairs appear at some distance rom the root-tip, in the region of the root, where growth n length has ceased. The root-hairs are the tubular protrusions of the epidermal cells. Each root-hair conists of a thin cellulose cell wall which is mucilaginous xternally and encloses vacuolated protoplasm, so long s it is in a living condition and continues to function.

In general root-hairs have only an ephemeral existence. They die off close to the conducting region and new ones arise in front, so that the root-hair region may retain its average area. Root-hairs vary in length from a fraction of a millimeter to about ten millimeters. They occur in very large numbers averaging about four hundred and twenty in a square millimeter of space in *Zea Mays.* The function of root-hairs is absorption of water and fixation in the soil.

To get an idea of the internal structure of a dicotyledonous root, the root of *Dolichos Lablab* may be chosen. A transverse section of this root taken through the elongating region will show distinctly two parts, namely, a very broad bulky cylinder called the **primary cortex** and a central core of tissue, consisting relatively of small cells, called the **stele.** The cortex will have on it a superficial covering consisting of an unbroken series of thin-walled cells or the **epidermis.** If followed upwards towards the apex the stele will be found to be continuous with the plerome, the cortex with the periblem, and the epidermis with the dermatogen. In the transverse section the cut ends of procambial strands, or those of xylem vessels will be present in the stele. In the longitudinal sections the nature of the xylem vessels or of the procambial strands can be made out. The xylem vessels are the beginnings of the water-conducting channel. As these vessels are surrounded by parenchymatous cells, their cavity may become obliterated and, as a protection against this, inside the thin walls of the vessels, thickenings occur either as isolated rings, or in the form of a continuous spiral. As this part of the root is still growing in length, the successive turns of the spiral or the rings may be pulled apart. So long as these rings or spirals are not separated too widely, they are not likely

to be affected by the turgidity of the surrounding parenchyma.

In a section taken through the root-hair region of the root the outermost layer consists of a layer of cells many

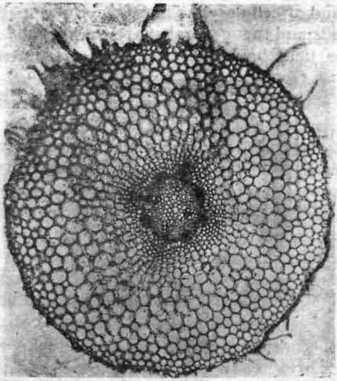


Fig. 178.—Transverse section of the root of *Dolichos Lablab* taken through the root-hair region.

of which are extended outwards as root-hairs. Hence this layer is called the **piliferous layer**. All the cells of the primary cortex are parenchymatous and they are in close contact with one another, but intercellular spaces are present. The innermost layer of the cortex consisting of cells, different in appearance from those of the cortex, is called the **endodermis**. It usually consists of rectangular prismatic cells, all continuous and in close contact laterally without intercellular spaces. In the

transverse section the radial walls show a dark spot called Caspary dots. These dots are the cut ends of a thickened band of *cutin running* all *round* each cell, along its radial and transverse walls. The inner and the outer tangential walls of the cells of the endodermis are thin and of cellulose. The endodermis on account of these bands and the general shape of its cells sharply marks the limit between the cortex and the stele. In

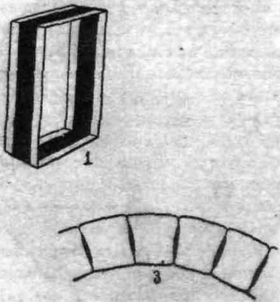


Fig. 179.—Endodermal cells showing the Caspary dots and the bands. 1, a single cell of the endodermis; 3, transverse section of endodermal cells.

dicotyledonous roots the endodermis possesses these characteristics only for a short time, but afterwards it becomes indistinct. But in monocotyledonous roots this layer persists and the cells become thickened laterally and internally. Besides the formation of the internal endodermis, in the monocotyledonous roots, the bulky cortex forms externally a layer called **exodermis**, just below the piliferous layer. The cells of the exodermis fit close together without intercellular spaces and their walls become suberised.

Although it may consist of one layer when young, it is usually several layered. It is a living physiological barrier.

The outermost layer of cells of the stele abutting on the endodermis forms the **pericycle**. In roots the pericycle consists always of a single layer of cells. The most prominent tissues in the stele are the four distinct groups of thick-walled cells lying at equal distances from one another, called the **xylem strands** or bundles. These xylem bundles abut on the pericycle and the vessels with small cavities close to it are the first formed vessels and consist of annular and spiral vessels. These constitute the **protoxylem**. The vessels of the xylem bundles get larger and larger, as we proceed from the periphery to the centre of the stele. These internal vessels with widest lumen are formed later and usually consist of reticulated and pitted vessels. In contrast to the protoxylem these vessels with wider lumen are designated **metaxylem**. Thus it is obvious that annular, spiral, reticulated and pitted vessels follow in order from without inwards. In other words, the development of the vascular bundle in the primary root is **centripetal.**

Alternating with these we find four phloem strands. These together with the xylem bundles constitute the vascular bundles. The xylem and the phloem bundles lie on distinct radii and hence they are said to be **radial.**

The phloem strands are distinct only in somewhat older sections passing through the root-hair region, because along with the sieve-tubes and the parenchyma cementing them, sclerenchymatous fibres appear. In roots younger than this the phloem strands are not strongly developed and so they cannot be distinguished easily from the surrounding conjunctive parenchyma.

The phloem consists of mainly sieve-tubes cemented together by phloem parenchyma. In somewhat older roots sclerenchyma fibres are formed externally to the

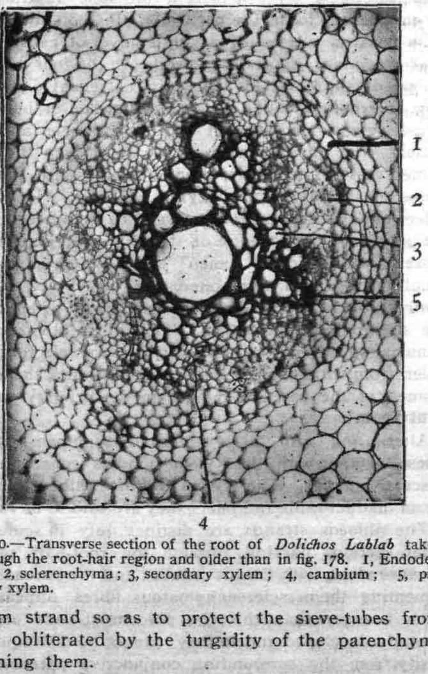


Fig. 180.—Transverse section of the root of *Dolichos Lablab* taken through the root-hair region and older than in fig. 178. 1, Endodermis; 2, sclerenchyma; 3, secondary xylem; 4, cambium; 5, primary xylem.

hloem strand so as to protect the sieve-tubes from eing obliterated by the turgidity of the parenchyma djoining them.

In the primary root the spaces between the vascular bundles and the pericycle are filled up by parenchyma. The four xylem bundles grow towards the centre of the stele and consequently they all meet in the centre. Thus all the lignified tissues become closely united into a mechanical central resistant cord so essential for the root, to withstand the longitudinal tension.

In sections of roots taken through the older portions of the root-hair region or younger portions of the conduct-

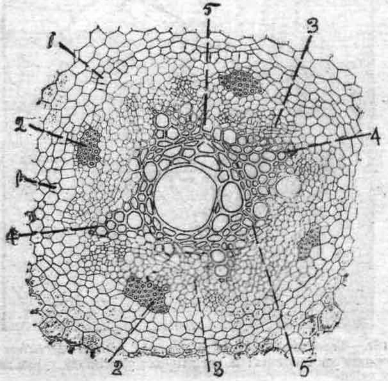


Fig. 181.—Transverse section of the root of *Dolichos Lablab.* Same as 180, but some what diagrammatic. 1, endodermis; 2, sclerenchyma; 3, cambium ; 4, primary xylem ; 5, secondary xylem.

ing region, the differentiation of the tissues will be very marked and in general there will be an increase in xylem elements. In such a section all the four primary xylem bundles would be found welded together by the

formation of xylem elements in the centre. Further, in the parenchyma lying between the xylem and phloem cell divisions appear. By this activity arcs of cambial tissue are formed internally to the phloem. Then the pericycle lying next to the protoxylem begins to divide and forms with bits of cambium, already formed, a cylinder of cambium.

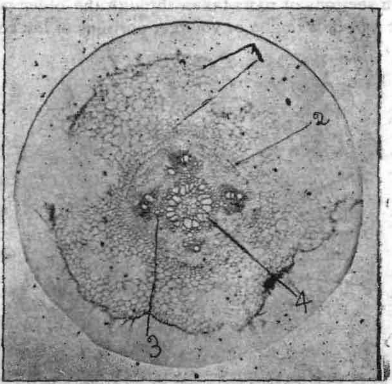


Fig. 182.—Transverse section of an old root of *Dolichos Lablab.* (Low-power) 1, cortex; 2, cork tissue; 3, primary xylem; 4, secondary xylem.

This cambium produces parenchymatous cells both inside towards the xylem and outside towards the phloem. The parenchymatous cells arising at the back of the four primary xylem groups appear as four broad medullary rays. Such of the parenchymatous cells as are close to the phloem become part of the phloem changing into sieve-tubes or remaining as

phloem parenchyma. Those cells which abut on the xylem get gradually changed into xylem-elements. Simultaneously with these changes the parenchyma of the cortex undergoes changes. The parenchymatous cells lose their protoplasm and become filled with air. As soon as the cells of the cortex become dead, they gradually peel off and protection is afforded by the secondary cortex formed of cork tissue.

Formation of cork tissue by the activity of the pericycle begins in the root of *Dolichos Lablab* long before

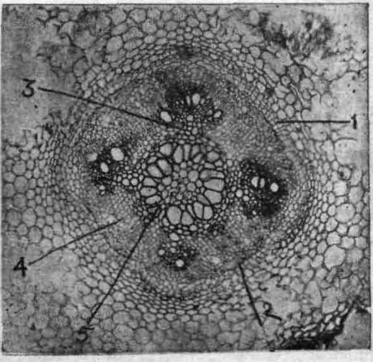


Fig. 183.—Transverse section of an old root of *Dolichos Lablab* showing the stele and a portion of the cortex. (High power) 1, cork tissue; 2, sclerenchyma; 3, primary xylem; 4, cambium; 5, secondary xylem.

the stripping off of the dead cortex cells. Soon after the cambium ring is well established, the pericycle begins to divide all round and form cork tissue and,

consequently, the cortical cells die and gradually th cortex wears out, and its place is taken by the cork whose development is continued by cork-cambium. S a transverse section of an old root is devoid of th primary cortex and the stele only persists, and th protective tissue cork is formed from the pericycle. An old dicotyledonous root acquires a structure very simila to that of an old stem on account of the activity of th cambium ring.

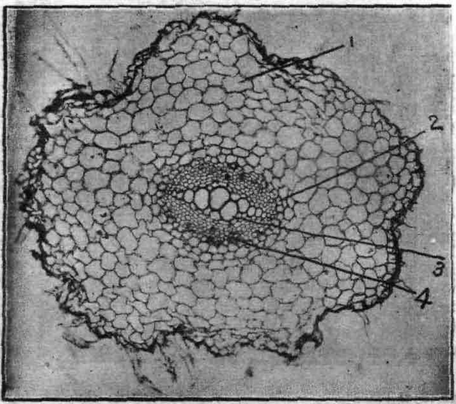


Fig. 184.—Transverse section of a root of *Raphanus*. 1, cortex; 2, pericycle; 3, primary xylem; 4, primary phloem.

In all essential features the roots of dicotyledonous plants resemble the roots of *Dolichos Lablab* so far as

their internal structure is concerned. But, however, dicotyledonous roots vary in the number of primary xylem strands. They may be two as in the roots of *Raphanus* and *Brassica*; three as in the roots of plants of the family Compositae; four as in the roots of *Benicasa cerifera* and legumionous plants; or five or six as in the roots of *Ricinus communis*.

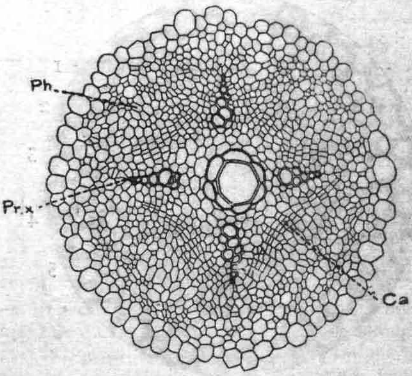


Fig. 185.—Transverse section of a root of *Benincasa cerifera*. Ph, phloem; Pr. x, primary xylem; Ca, cambium.

As an example of monocotyledonous root we may study the root of onion. In a transverse section of the onion root a broad cortex is seen to surround the stele. The endodermis is well marked. Within the stele are present seven groups of xylem vessels. Alternating with these seven primary xylem groups there are seven

groups of phloem. Each group of xylem is composed of smaller vessels close to the periphery and touching the pericycle, with vessels in front getting larger and larger towards the centre where all the groups meet. The smaller vessels are annular and spiral vessels constituting the **protoxylem,** and the later-formed pitted vessels form the **metaxylem.** No cambium is formed.

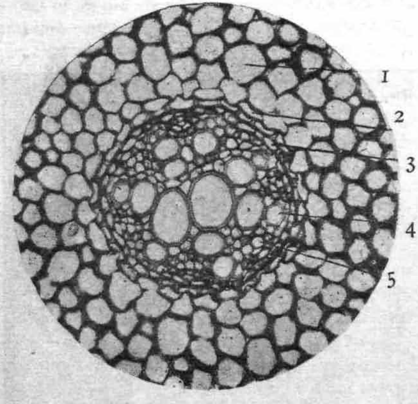
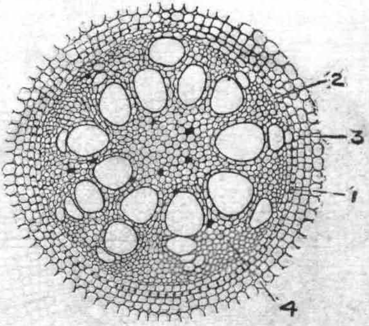


Fig. 186.—Transverse section of a root of onion. 1, cortex; 2, endodermis, 3, pericycle; 4, protoxylem; 5, phloem.

So the monocotyledonous type of root maintains its primary structural conditions throughout.

In transverse sections of *Colocasia* root there will be nine to eleven primary xylem groups. The endodermis is well marked and the cortex is broad consisting of parenchyma with intercellular spaces.

As further examples of monocotyledonous type of root, we may examine the roots of *Andropogon Sorghum*, *Pennisetum cenchroides* and *Musa paradisiaca.*



Fig, 187.—*Transverse section of a root of Colocasia showing the* stele. 1, endodermis; 2, pericycle; 3, protoxylem; 4, phloem.

In a transverse section of the root of *Andropogon Sorghum* we find a fairly broad cortex surrounding the stele. The inequality between the cortex and the stele is not so great as in the onion or *Colocasia* root. Outside the cortex there is a distinct piliferous layer. Immediately below this layer the exodermis is formed. In roots that are aerial the exodermis is very well developed, and the reason for this will become obvious after the study of the structure of the stem. The endodermis also is quite distinct. The inner tangential walls of the endodermal cells are lignified. Within the stele there are a large number of primary xylem groups and as many phloem groups also. The major portion of the stele in the centre

consists of parenchyma. When the root gets older the cell walls of the pericycle and of the parenchymatous cells in the centre become thickened so that the lignified tissues

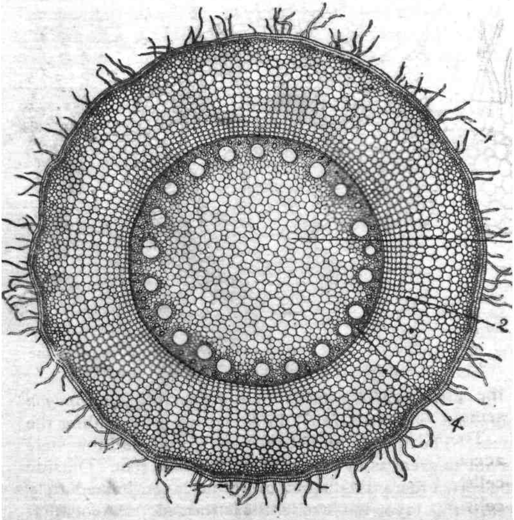


Fig. 188.—Transverse section of a root of *Andropogon Sorghum*. 1, root-hair; 2, cortex; 3, pith; 4, protoxylem groups

are all welded together into a central mechanically resistant strand.

The structure of the root of *Pennisetum cenchroides* in transverse section is shown in fig 193. The general

structure and arrangement of tissues is practically similar to that of the root of *Andropogon Sorghum*. But the stele is larger and the cortex is comparatively narrower.

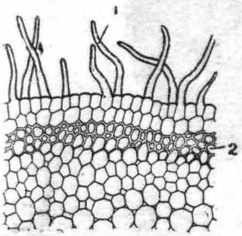


Fig. 189.—Transverse section of a portion of the cortex with piliferous layer of *Andropogon Sorghum*. 1, root-hair; 2, exodermis.

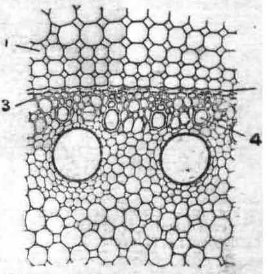


Fig. 190.—Transverse section of a portion of the stele of *Andropogon Sorghum*. 1, cortex; 2, endodermis; 3, pericycle; 4, protoxylem

The root of *Musa paradisiaca*, though conforming to the general monocotyledonous type of structure, presents certain special features.

The layer of endodermis is a very striking layer on account of the great thickening of the inner wall of its cells. Next to this lies the pericycle as a single layer of cells.

Within the stele there are more than thirty groups of primary xylem alternating with as many groups of phloem, and all these are at the periphery of the stele abutting on the pericycle. The central portion of the stele is occupied by numerous xylem vessels, and there are also phloem groups irregularly disposed amidst the xylem. The cortex presents no special features, except

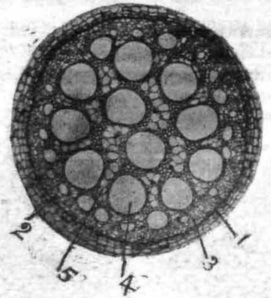


Fig. 191.—Transverse section of the stele of *Musa paradisiaca* 1, endodermis; 2, primary xylem; 3, primary phloem; 4, secondary xylem; 5, phloem.

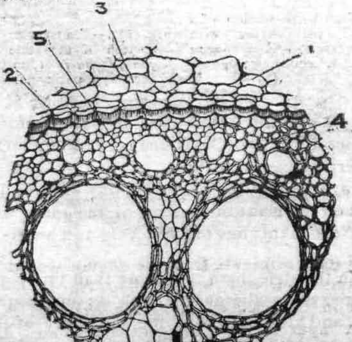


Fig. 192.—Transverse section of a bit of the stele of *Musa paradisiaca* 1, cortical cells; 2, endodermis; 3, pericycle; 4, protoxylem; 5, phloem.

the very regular arrangement of the cells with uniform intercellular spaces. Another marked feature is the lignification of the walls of all the cells within the stele, except the elements of the phloem. The exodermis is not so well developed in this root.

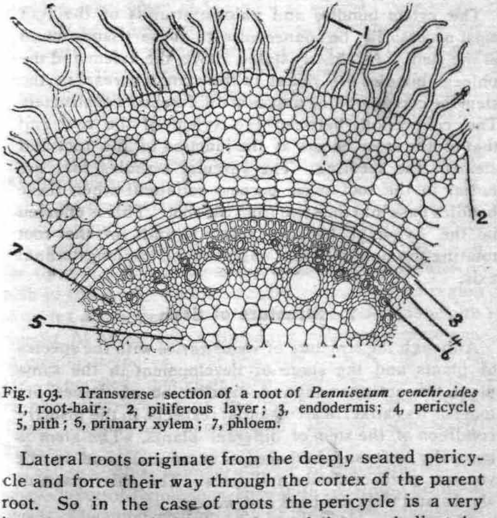


Fig. 193. Transverse section of a root of *Pennisetum cenchroides* 1, root-hair; 2, piliferous layer; 3, endodermis; 4, pericycle 5, pith; 6, primary xylem; 7, phloem.

Lateral roots originate from the deeply seated pericycle and force their way through the cortex of the parent root. So in the case of roots the pericycle is a very important layer in both monocotyledons and dicotyledons. Every lateral root springs from the pericycle usually at a point close to one of the protoxylem groups. In dicotyledonous roots, there will be as many longitudinal rows of lateral roots as there are protoxylem

groups. For instance, we see in the tap-root of *Dolichos* seedling four longitudinal rows of lateral roots, and the protoxylem groups are usually four in this root. The roots of *Raphanus* and *Brassica* have only two protoxylem groups and, therefore, we find in these roots only two rows of lateral roots.

The xylem bundles and phloem strands of the root must necessarily be connected with these tissues found in the stem. As already stated above, the xylem and the phloem bundles are radial in the root, whereas in the stem the corresponding tissues are differently constructed. The connection between the xylem of the root and that of the stem occurs at the junction of the root and stem of the seedling. The vascular bnndles that are radial in the root must become collateral when these bundles pass into the stem from the root. This is effected in the hypoctyl by the xylem strands of the root rotating through two right angles round the longitudinal axis.

2. Structure of Stem

Although the structure of stems varies with the species of plants and the stage of development in the same plant, the arrangement and distribution of tissues are more or less alike, in all essential respects, in the primary condition of the stem of different plants. The stem is generally soft and herbaceous in annuals and in the younger parts of shrubs and trees. The older parts of shrubs and trees are hard and woody.

The structure of the growing point of the stem is the same in all angiospermous plants, so far as the essential features are concerned. It consists of a mass of meristematic cells terminating in a cone and covered by the developing young leaves. Axillary branches arise very

early as protuberances in the axils of leaves near the actual growing point. They remain dormant for a long time. It is the leaf that grows rapidly one after the other, while the axis does so very slowly. In consequence of this difference in growth between the axis and its appendages, the young leaves developing near the growing point cover and protect it.

To get an exact idea of the internal structure of stems of plants it is necessary to select as types a few plants, and study the tissues and their arrangement in transverse and longitudinal sections of the stems of plants so selected. We shall take as types the stems of the plants *Helianthus annuus*, *Hibiscus cannabinus*, *Aristolochia bracteata*, *Cucurbita maxima* and *Thespesia populnea* for dicotyledons.

A transverse section of the stem of *Helianthus annuus*, taken an inch or two below the growing point, consists of a number of isolated vascular bundles arranged in the form of a ring enclosing a large area of **medulla** or **pith** in the centre, and separating it from a narrow region of cortex at the periphery. Both the cortex and the pith consist of living parenchymatous cells with numerous intercellular spaces. The vascular bundles themselves are separated one from the other by broad bands of parenchyma uniting the medulla with the cortex. These bands of parenchyma are the **medullary rays**.

The superficial boundary layer of the epidermis is a single layer of living cells, each with its lining of protoplasm. The outer wall of each of these cells is thickened and there is also a very thin layer of cutin. Beneath the epidermis lies the cortex consisting of several layers of cells. The innermost layer of the cortex consists of cells containing starch grains and this is the **endodermis**.

Although this layer delimits the stele from th
cortex in young stems, in older stems this layer canno
be distinguished easily. The outermost layer of cells o
the cortex contains chloroplasts, if the stem is a ver

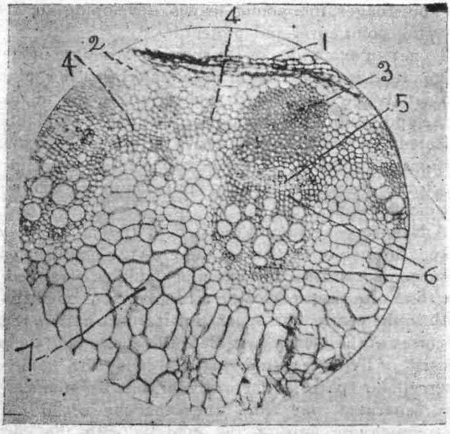


Fig. 194.—Transverse section of a portion of the stem of *Helianthu annuus.* 1, epidermis; 2, cortex; 3, sclerenchyma; 4, cambium; 5 phloem; 6, xylem; 7, pith or medulla.

young one. This is succeeded by a number of layers of collenchymatous cells. Below collenchyma there are a few layers of ordinary parenchymatous cells. In the cortex there are seen here and there resinducts. Thus the cortex is seen to consist of a few layers of collenchyma overlying some layers of parenchyma, and delimited

internally by the endodermis. Resin passages also occur in the cortex of this stem.

The central core of tissues in the stem surrounded by the endodermis is the stele. The most prominent tissue

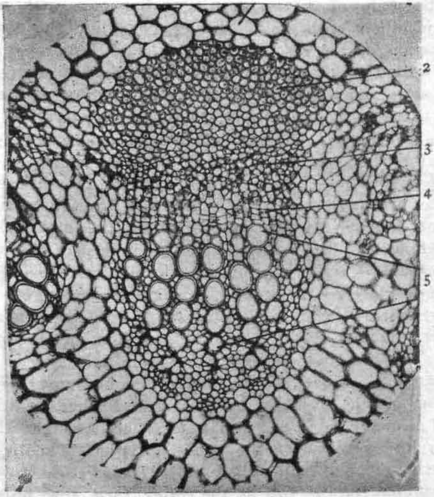


Fig. 195.—Transverse section of a single vascular bundle in the stem of *Helianthus annuus*. 1, cortex-cells; 2, sclerenchyma; 3, phloem; 4, cambium; 5, xylem.

in the stele is the vascular tissue occurring as distinct bundles arranged in the form of a ring around the medulla. The parts and general features of these

bundles may be made out by studying a single vascular bundle in both transverse and longitudinal sections under the high power of the microscope. The appearance of a single vascular bundle in a transverse section of the stem is shown as a photomicrograph in fig 195. The groups of cells with thick walls, some with large and others with small cavities, constitute the **xylem** portion of the vascular bundle. The larger cavities bounded by thick walls and in regular rows are the vessels. The smaller cavities with slightly thickened walls are either parenchymatous cells with lignified cell walls or fibres. The lignified vessels, wood parenchyma and fibres constitute the elements of the xylem of the vascular bundle. Vessels lying close to the pith form the **protoxylem** and those far away from the pith are later-formed vessels and constitute the **metaxylem**. Behind the xylem towards the periphery of the stem lie several layers of thin-walled cells. Of these cells those close to the xylem are regularly arranged and are narrowly rectangular in shape. These constitute the **cambium**. The cells of the cambium are produced by cell divisions occurring in the initial layer or the cambium proper. The cambium is the most delicate part of the vascular bundles, and further additions of elements to xylem and phloem are brought about by the activity of the cambium layer. The irregularly grouped thin-walled cells lying close to the cambium on the side of the cortex form the **phloem** portion of the vascular bundle. The phloem is really made up of sieve-tubes and parenchymatous cells. Between the endodermis on one side and phloem on the other we find a bundle of sclerenchyma. This bundle of sclerenchyma does not form part of the vascular bundle and hence we often use the term **fibro-vascular**

bundle to denote that fibres are associated with the vascular bundle. The bundles of sclerenchyma together with the part of the medullary ray between them form a continuous ring, just outside the vascular bundles and inside the endodermis. This part is therefore the outermost part of the stele and constitute the **pericycle.** In stems the pericycle is usually many-layered and may be uniform or may consist partly of parenchyma and partly of sclerenchyma.

To understand the nature of the elements of the various parts of a vascular bundle it is necessary to examine a

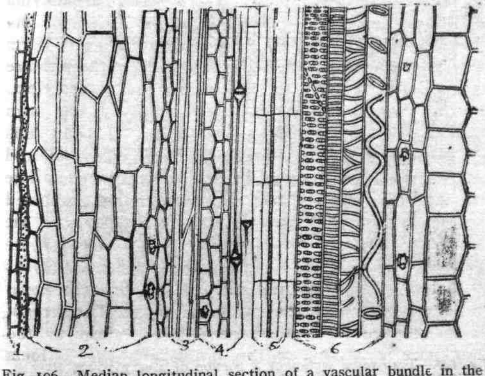


Fig. 196.—Median longitudinal section of a vascular bundle in the stem of *Hibiscus cannabinus*. 1, epidermis; 2, cortex; 3, sclerenchyma; 4, phloem; 5, cambium; 6, xylem. Note the initial layer of the cambium.

median longitudinal section. Such a section of the vascular bundle of a stem is shown in figure 196. The pith and cortex consist of thin-walled parenchyma. The

outermost layer of the stem consists of flattened thin-walled cells and it is the epidermis. Between the cortex and the pith lie the various elements of the vascular bundle. The cortex consists of somewhat elongated parenchymatous cells, and next to it and inside towards the stele we find fibres. Sieve-tubes occur close to the fibres and the cambium lies between this and the xylem. Pitted vessels lie close to the cambium and in front of these vessels come spiral vessels.

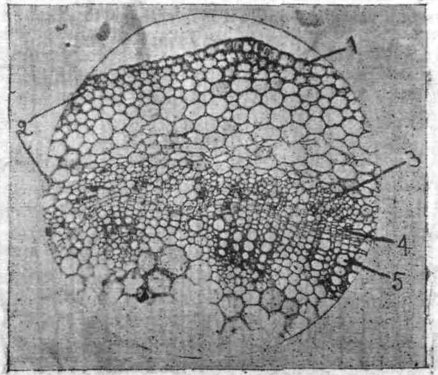
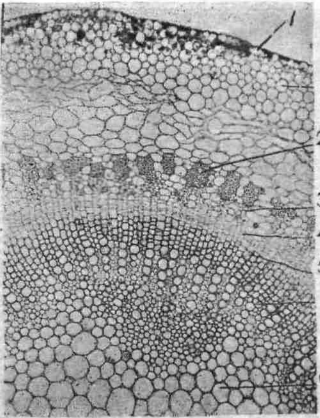


Fig. 197.—Transverse section of a portion of a very young stem of *Hibiscus cannabinus* 1, epidermis; 2, cortex; 3, phloem; 4, cambium; 5, xylem.

As already stated, the medullary rays separating the bundles are generally broad and consist of parenchymatous cells. They run from the pith to the cortex and hence they are called **primary medullary rays**. As the

em gets older and older the primary medullary rays et narrower and narrower, because of the formation of ew vascular bundles in the primary medullary rays. See fig 194.) So long as the vascular bundles are sepa-ıte, the whole of the medullary ray consists of paren-hyma. But as soon as the xylem becomes a continuous



ig. 198.—Transverse section of a portion of the stem of *Hibiscus cannabinus* older than in fig. 197. (Low power). 1, epidermis; 2, sclerenchyma; 3, phloem; 4, cambium; 5, xylem; 6, medulla.

ng, that part of the ray which runs through the xylem ecomes differentiated into wood parenchyma and the ells contain in most cases starch grains. Such medul-ıry rays run right through the xylem or they may run

only to a certain distance. The former are primary and the latter **secondary medullary rays.**

The stem of *Hibiscus cannabinus* does not differ very much from that of *Helianthus annuus* in its internal structure. A transverse section of a very young stem of this plant is shown in figure 198. The outermost layer

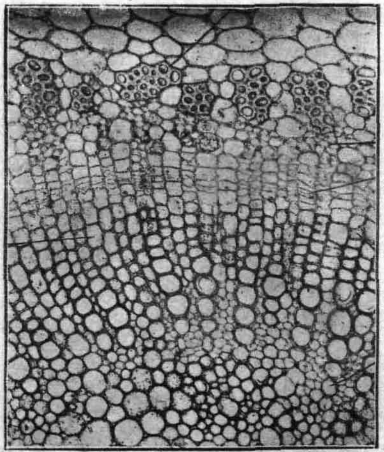


Fig. 199.—Transverse section of a portion of the stele in the stem of *Hibiscus cannabinus* (high power). 1, sclerenchyma; 2, phloem; 3, cambium; 4, protoxylem; 5, metaxylem.

is the epidermis. Below this lies a narrow band of cortex consisting of a few layers of parenchymatous cells with intercellular spaces. The endodermis can be made

out. The stele consists of a large amount of pith surrounded by numerous small vascular bundles separated by very narrow medullary rays. The cambium is fairly broad and conspicuous. In older stems the vascular cylinder becomes quite continuous. Another striking character in this stem is the presence of groups of fibres

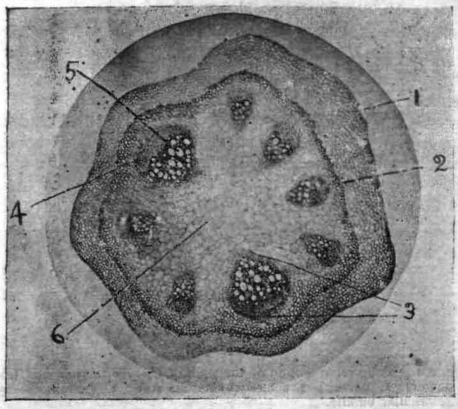


Fig. 200.—Transverse section of the stem of *Aristolochia bracteata*. (Low power) 1, cortex; 2, sclerenchymatous band forming the outer portion of the pericyle; 3, vascular bundle; 4, phloem; 5, xylem; 6, medulla or pith.

in the phloem alternating with sieve-tubes and thin-walled phloem parenchyma. The details of the structural features of this stem can be made out by reference to the figures 198 and 199.

In a transverse section of the stem of *Aristolochia bracteata*, we clearly see the epidermis, the cortex and the stele. (See fig 200.) Within the stele there are a number (5 to 11) of vascular bundles separated by very broad medullary rays. The vascular bundles consist of xylem, phloem, with cambium between them. The endodermis is distinct because the layers of cells inside

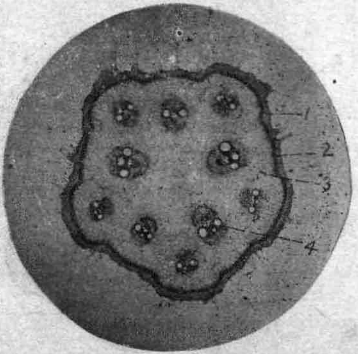


Fig. 201.—Transverse section of the stem of *Cucurbita maxima*. (Low power) 1, cortex; 2, sclerenchymatous ring; 3, medullary ray; 4, vascular bundle.

in contact with it are thick-walled. Between the endodermis and the vascular bundles we find two distinct continuous bands. The layers of cells with thick walls are the fibres, and instead of being in the form of separate bundles as in the stem of *Helianthus*, they form a continuous ring. Below this ring of fibres there is a broad band of parenchyma. These two layers together constitute the pericycle. The epidermis has a cuticle

and the central part of the stele is pith. In this stem the interfascicular cambium makes its appearance gradually and slowly.

The structure of the stem of *Cucurbita maxima* presents certain special features. The superficial layer, like that

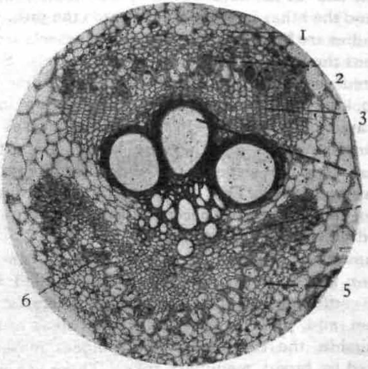


Fig. 202.—Transverse section of a vascular bundle in the stem of *Cucurbita maxima*. 1 and 5, phloem; 2 and 6, sieve-tubes; 3, cambium; 4, xylem.

of other stems, forms the epidermis. The epidermal-cells bear hairs externally. Compared with other stems the cortex is narrow and the stele is fairly broad. The peripheral portion of the stele abutting on the innermost layer of the cortex possesses a number of layers of sclerenchymatous cells forming a continuous band running round the stem. This sclerenchymatous band with the thin-walled layers of cells lying outside

the vascular bundles forms the pericycle. Within the stele there are two series of vascular bundles, of which the five outer smaller ones alternate with the five inner larger bundles. The central part of the stem is hollow. In the vascular bundle there are two sets of phloem, one at the back of the xylem next to the cambium and the other in front of it towards the pith. Hence the bundles are **bicollateral**. The xylem vessels are fairly numerous the larger ones being pitted vessels. Some of the pitted vessels have cells growing into their cavity and blocking the passage. Such cells growing into the cavity are called **tyloses**. In the phloem masses sieve-tubes are numerous and they are large. Longitudinal sections show the sieve-plates and the contents of the tubes very clearly. The threads passing through the pores of the sieve-tube become obvious when stained with iodine or Hoffman's blue.

A transverse section of a year old stem of *Thespesia populnea* has a well marked pith surrounded by an almost continuous hollow cylinder of xylem, a broad cambium and phloem masses arranged so as to form a ring outside the cambium. The phloem masses are separated by broad medullary rays. There is a narrow cortex consisting of a thin band of collenchyma overlying a few layers of parenchymatous cells. The epidermis is found as a superficial layer but the cells are dead and in some places it may be found ruptured. Below this dead epidermis and above the collenchyma, lie layers of cells all regularly arranged and without any intercellular space. This is cork tissue. The epidermis keeps pace with the growth in thickness of the stem up to a certain limit, and then this work of protection is done by cork tissue. Long before the epidermis is about to become dead and cease to function, a layer of parenchymatous

cells in the cortex, below the epidermis, becomes meristematic and a cork-cambium is formed. This cambium goes on producing cork cells forming the cork tissue.

A woody stem has fundamentally the same structure that is found in a herbaceous type of stem, though there are differences. After all the differences between a herbaceous stem and a woody stem lie in the relative proportions of the different tissues and in the formation of cork. The cambium is more active and there is a large increase in every tissue. There is provision for indefinite expansion. In a woody stem the xylem portion is the most prominent thing, as it is increasing in amount due to the activity of the cambium. The primary cortex becomes the bark by the formation of cork, fibres and sclerotic cells. What we call bark in a woody stem really consists of cork tissue, parenchyma, and fibres forming part of phloem. The bark is capable of adjusting itself admirably to the bulk of the growing stem. The medullary rays become conspicuous. They are narrow plates of tissue extending from the cambium to the pith or stopping short of it in the radial direction. Their vertical extension is not much and their ends are somewhat lenticular in shape. Inasmuch

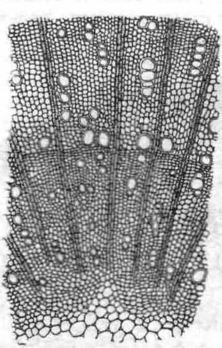


Fig. 203.—Transverse section of a portion of a woody stem showing medullary rays. (Low power).

as the cells of these rays consist of pitted wood-parenchymatous cells filled with protoplasm and starch, these link the phloem and the xylem and form a connected system of living tissue extending inwards and outwards. If we bear in mind that a tree has to withstand a great deal of external mechanical force, that large amounts of water pass away from the leaves and that large amounts of food material have to be stored and translocated to various parts, then it becomes obvious that it should have in its stems a large amount of xylem and also a well developed bark.

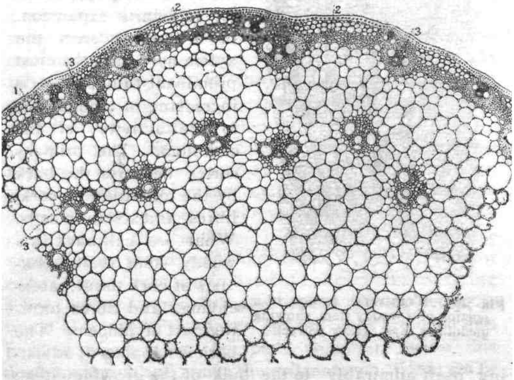


Fig. 204.—Transverse section of a portion of the stem of *Setaria glauca*. 1, epidermis; 2, sclerenchyma; 3, vascular bundle.

The structure of the stem of monocotyledons is different from that of the dicotyledonous stems. As types of monocotyledons the stems of cereals and grasses may be

examined. In a transverse section of the stem of a grass the vascular bundles are found scattered amidst a mass of parenchymatous cells. The vascular bundles consist of only xylem and phloem, without the cambium, and so there cannot be secondary thickening, and such bundles are called closed vascular bundles. A distinct medulla is wanting as the vascular bundles are scattered within the stele. The cortex is distinct though narrow, and the *endodermis* can be made out in certain stems.

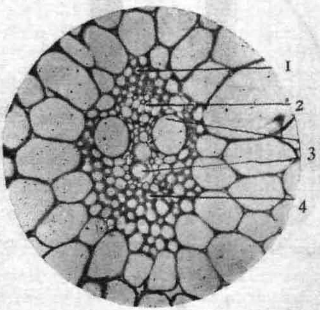
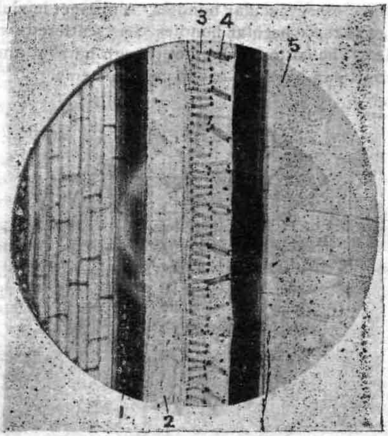


Fig. 205.—Transverse section of a single vascular bundle of a monocotyledonous stem. 1, and 4, sclerenchymatous fibres; 2, phloem; 3 xylem;

The xylem consists of a few vessels and wood-parenchyma, and they are arranged in the form of a 'V' with wood-parenchyma and small vessels wedged in between the larger vessels. The phloem lies close to the xylem. All round the bundle we find fibres forming a kind of sheath which is well developed.

The cell walls of the cells of the epidermis and of one or two layers of the cortex lying immediately beneath the epidermis become thickened. Further the scleren-chymatous sheaths of the vascular bundles lying at the



ig. 206.—Longitudinal section of a vascular bundle of a monocotyledonous stem. 1, sclerenchyma; 2, phloem; 3, spiral vessel; 4, annular vessel; 5, parenchymatous cells of the conjunctive tissue.

eripheral portion of the stem are generally very broad nd much strengthened. By all this arrangment the uter portion of the stem becomes hard and stiff enabling to withstand the strain of wind and weight.

From what we have learnt about the structure of stems nd roots, we know that secondary thickening takes

place in both the roots and stems of dicotyledonous plants. Under normal conditions the formation of new cells causing an increase in their number, which is essential for the formation of new elements for the various tissues, is the work of the cambiums. But under abnormal conditions parenchyma that has become a permanent tissue may once again become active and give rise to different kinds of tissues. When a stem is injured various tissues are exposed to the air. Most of the cells of the cortex are living cells and so, when pressure is removed by injury, all these cells swell and some of them lying somewhat deeper begin to divide. As a result of this activity, a mass of cells is formed at the injured area and the outermost cells become changed into the protective tissue, cork. This mass of cells brought into existence by this abnormal activity is spoken of as **callus** and the process is termed **callus formation**. All wounds caused in the parts of plants are healed by this process only.

3. Internal Structure of Leaves

Leaves arise as lateral protuberances at the growing point of the stem. The very young leaf in its embryonic stage occupies only a small portion of the surface of the growing point, especially when the leaves are alternate. So a large number of leaves may arise within a small area of surface. A whorl of leaves arises at first as a ring, and leaves appear later as distinct structures. The embryonic protuberances which develop into leaves grow at their tips at first, at any rate more rapidly at the tip than at the base. So the upper portion of the leaf is first developed. Therefore the developing leaves protect the younger parts of the growing end of the stem. The leaf-base continues its growth long after the formation of the blade and until the leaf is fully developed.

The petiole usually resembles the stem in its internal structure in angiosperms. The vascular bundles are disposed in it as an arc open above. These bundles are without cambium, as no secondary thickening is required. In the cortex the collenchyma may be prominent.

In foliage leaves the netwok of veins is a very prominent feature. A typical leaf blade has a dorsiventral structure. In a leaf blade we can make out three distinct parts, namely, the upper and lower epidermis, the network of veins and the mass of prenchymatous cells constituting the **mesophyll** of the leaf.

The epidermis is a continuous layer consisting of flattened cells with their outer walls distinctly cutinised. The continuity of the epidermis is interrupted by stomata here and there. Each stoma is a pore bounded by a pair of semilunar cells called the **guard cells.** There are two types of guard cells, namely, the one found in the majority of monocotyledons and dicotyledons and the other occurring in grasses and sedges. In the former type the guard cells are semilunar and in the latter they are dumb-bell-shaped. Chloroplasts occur in the guard cells though the epidermal cells are free from them. Guard cells are capable of altering the size of the pore by changing their shape. Stomata are found in large

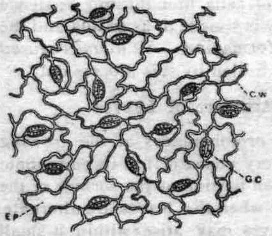


Fig. 207.—Epidermis from the lower surface of *Dolichos Lablab* leaf. Cw, cell wall. Gc, guard cell ; Ep, epidermal cell.

numbers in the lower epidermis although there are leaves having them on both sides.

The mesophyll tissue of the leaf lying between the upper and lower epidermis and occupying the meshes of

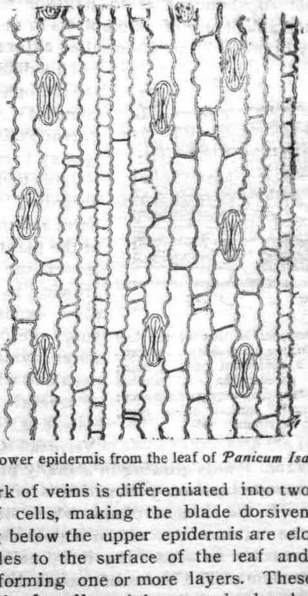


Fig. 208.—Lower epidermis from the leaf of *Panicum Isachne.*

the network of veins is differentiated into two different groups of cells, making the blade dorsiventral. The cells lying below the upper epidermis are elongated at right angles to the surface of the leaf and lie close together forming one or more layers. These cells are called **palisade cells** and they contain abundant chloroplasts. Below the palisade parenchyma lie irregularly shaped cells with wide intercellular spaces, constituting

the **spongy parenchyma**. The numerous wide intercellular spaces present in spongy parenchyma are connected with the stomata in the lower epidermis. Chloroplasts are present in the cells of spongy parenchyma also, but not so abundant as in palisade cells. On account of the abundance of chloroplasts in the cells of the mesophyll these cells are often called **chlorenchyma**.

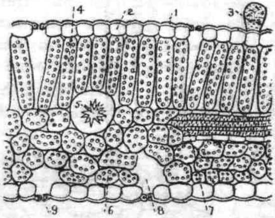


Fig. 209.—Transverse section of the leaf blade of ***Hibiscus cannabinus***. 1, cutinised layer; 2, epidermal cell; 3, hair; 4, palisade parenchyma; 5, calcium oxalate crystal; 6, spongy parenchyma; 7, longitudinal section of a vein; 8, air-cavity; 9, stoma.

This distinction of the mesophyll into a compact palisade parenchyma and spongy parenchyma, is liable to variations according to the habit and the species of the plant. In the leaves of a plant growing in an open place exposed to the sun, the palisade parenchyma will be deep and will consist of several layers of cells, e. g., leaves of *Nerium*, *Calotropis* and the banyan. Plants growing in a shady place have leaves with a single layer of palisade cells, e. g., *Vigna* and *Dolichos*. In the case of plants whose leaves are exposed to the light of the sun on both the sides, the mesophyll presents no separation into palisade and spongy parenchyma. The leaves of grasses do not show this differentiation, but the whole of the mesophyll consists of compactly arranged parenchymatous cells. Some of the cells of the epidermis, especially in the

upper epidermis, of the leaves of most grasses become larger and they are capable of containing large quantities of water so that they remain rigid or become flaccid when water is lost. These cells are called motor cells.

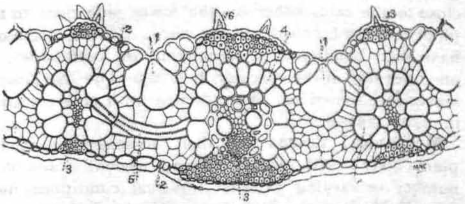


Fig. 210.—Transverse section of the leaf of *Eragrostis wildenoviana*. *1*, motor cell; *2*, epidermis; *3*, sclerenchyma; *4*, bundle sheath; *5*, longitudinal section of a vascular bundle.

The veins of the network of the leaves are continuations of the vascular bundles of the stem. Vascular bundles traversing the stem enter the petioles at the nodes, and ramify and anastomose in the blade forming the characteristic network of the leaf. The vascular bundles in larger veins have xylem and phloem with the full complement of their elements, and the bundles in the smaller veins contain fewer elements. The xylem is directed towards the upper and the phloem towards the lower surface of the leaf. The bundles get smaller and simpler in structure as the veins go on branching into smaller ones. The finer ultimate branches of the network end blindly and they consist of only reticulate and spiral tracheids. One or two sieve-tubes much reduced, but with complete companion cells, may be found associated with the xylem elements, and, however, they stop short of the very ends

of the ultimate branches. The vascular bundles in the veins are surrounded by a layer or layers of parenchymatous cells which are elongated and closely set without intercellular spaces. These are sometimes called bundle sheaths. Strands of sclerenchyma are also found close to the veins either on the lower side close to the phloem, or on both sides of the veins. Leaves of grasses have such bundles of sclerenchyma on both sides, or on one side of the vascular bundles. The margins of leaves are sometimes strengthened with sclerenchyma in many grasses.

Mechanical tissues and their arrangement in the plant body:--All plants growing normally amidst a number or varying external physical conditions have to maintain their form, if they are to do their functions properly. They must also be able to resist those stresses and strains that are likely to befall them in their ordinary course of life. The construction of the plant body must be such as to enable it to ward off the effects of strong winds and at the same time bear the weight of the branches, twigs and leaves.

The units of plant structure or cells have cell walls enclosing the protoplast and this makes it possible for them to secure the necessary firmness. Very young parts of plants are capable of maintaining their rigidity and firmness, as the cells of which they are composed remain in a turgid condition. Older parts have developed in them specific mechanical tissues and such tissues are the **collenchyma** and the **sclerenchyma**.

As all the parenchymatous cells in the younger parts of plants are active, it is necessary to have some kind of mechanical tissue, which would give rigidity and at the same time be elastic to allow the cells to grow. Collenchyma is just the tissue suited for young stems.

Collenchymatous cells do not impede the growth in length, but instead they themselves *grow with the* growth of the part they support, offering a persistent

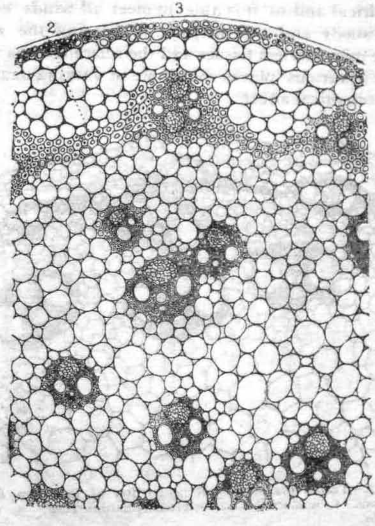


Fig. 211.—Transverse section of a portion of the stem of *Pennisetum cenchroides.* 1, epidermis; 2, sclerenchymatous ring; 3, vascular bundle.

though plastic resistance. The position of collenchyma is beneath the epidermis and this gives it a full mechanical effect.

The sclerenchyma is undoubtedly the most cha teristic mechanical tissue. The stem, the leaf and the root secure the necessary mechanical advantag the proper distribution of sclerenchyma. The sten cylindrical and so it is able to meet all winds equa It is woody and this helps it in bearing the wei

The mixed xylem tissues and the sclerenchyma dis buted in various places contribute in varying degree the mechanical effect.

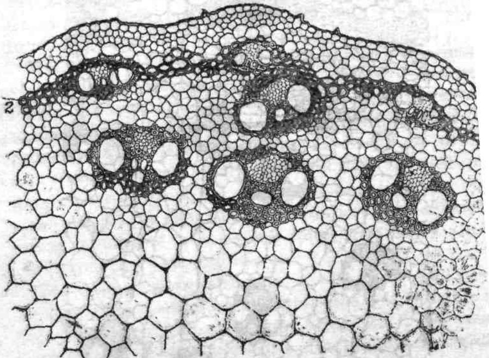


Fig. 212.—Transverse section of a portion of the stem *Panicum Isachne.* 1, epidermis; 2, sclerenchymatous ring; 3, vascular bundle.

The fibres forming a sheath around the vascular bundles of the monocotyledonous stem and the groups of fibres forming a part of the pericycle in the stems of Sunflower, *Cucurbita* and *Aristolochia* play a very important part in the life of the plant. These sclerenchymatous bands enable the stems of these plants

to withstand the strain of wind. If we closely observe the disposition of the fibre bundles in these stems, we notice that the stems are strictly comparable to a hollow cylinder with very great firmness and rigidity at the periphery. A hollow cylinder is really a combination of several girders. In most stems of grasses the mechanically effective tissue sclerenchyma is found distributed towards the periphery. We find continuous sclerenchymatous bands in the stems of some grasses at the periphery with many vascular bundles imbedded in them.

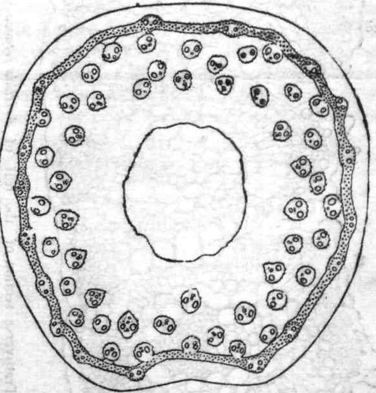


Fig. 213.—Transverse section of the stem of *Eragrostis interrupta* showing the peripheral sclerenchymatous ring.

Leaves have an expanded structure which is absolutely necessary to perform their functions. The crushing of the mesophyll is effectively prevented, when leaves are

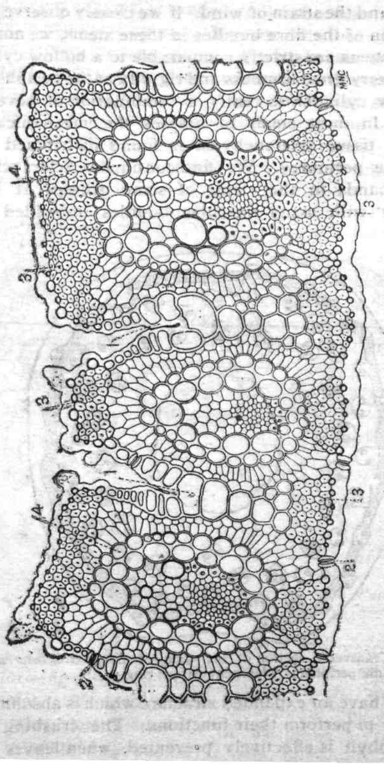


Fig. 214.—Transverse section of the leaf of *Aristida setacea* showing the arrangement of sclerenchymatous band. 1, motor cells; 2, stomata; 3, sclerenchymatous band; 4, bundle sheath.

bjected to winds, by the net work of veins. In many aves the veins are arched and at the margins scleren-ıyma is found. By this means marginal tearing of e leaves is effectively prevented. The lower and upper ›idermis also form a firm skin over the mesophyll. In ıe leaves of monocotyledons, especially grasses, scleren-ıymatous bands follow the veins on either side forming ith each a girder.

Roots are subjected to longitudinal tension, as they ear the weight of the shoot which is swayed by winds. o enable the roots to resist the longitudinal tension the entral core becomes hardened. In some roots, especially ıose of dicotyledons, the central pith portion is filled ith xylem elements. In monocotyledonous roots the rimary xylem groups do not reach the centre and in ıese cases the parenchyma in the centre of the pith hanges into hard cells by lignification of the cell walls. o in these roots also the central core becomes welded ›gether into a solid mass to offer resistance effectively.

SECTION II
PHYSIOLOGY

CHAPTER XIII

ABSORPTION AND MOVEMENT OF WATER AND NUTRIENT SALTS WITHIN THE PLANT

LAND plants have to use for the preparation of their food, so necessary for their growth, only such of the raw materials as are available in the soil and the atmosphere. The nutrient substances that exist in the soil and which the plants make use of in the preparation of their food are water, certain salts dissolved in water and gases.

From a study of germination of seeds we have already learnt that water is indispensable for the life of the plant. The very maintenance of the form of the plant when young is entirely dependent upon the presence of water in large quantities. All the chemical changes occurring in plants are carried out only in watery solutions. The protoplasm which is the physical basis of life can be active only when it contains 75 per cent or more of water. The amount of water which a woody plant possesses is about 50 per cent, and a succulent plant may contain as much as 95 per cent of water. In plants a very large portion of the water appears as liquid water in the cavities of vessels and in the vacuoles of protoplasm. Besides this a fair amount of water is found in the substance of cell walls, protoplasm and starch grains. The swollen condition is due to this water and it is termed water of imbibition.

For the escape of the embryo from the seed-coat and its further growth water is essential. All the cells in the

cotyledons and in the primary axis become filled with water almost to the point of saturation. By this the living cells become active, and the activity is kept up all through the life of the plant. So long as there is sufficient amount of water in these cells they perform their functions, but any diminution in water affects these functions and, if the loss of water is much, the life of the plant may be destroyed. However, if the diminution is not great, cessation of work will be only temporary and resumption of work follows, as soon as the loss of water is made good.

All the water that a land plant absorbs is taken from the thin films of water, adhering to the soil particles. Soil, as we know, consists of particles of sand of different sizes, some coarse, others small and yet others very fine. Besides these grains of sand there are in the soil the remains of living organisms, reduced by the process of decay into various organic substances collectively termed humus. Calcium carbonate and calcium phosphate may also be present. Any ordinary soil will contain all these substances and will be porous. The air spaces in the soil contain atmospheric air. Soon after rain, water soaks into the soil. A very large amount of this water, however, is drained away, and by evaporation also a certain amount of water is lost. In spite of these two sources of loss, a fair amount of water will still remain adhering to the soil particles as thin films. And this is the main source of supply of water to all land plants.

The part of the plant which takes up water from the soil is the root-system, but the parts directly concerned in this work are, however, the root-hairs, clothing the young parts of roots just close to the root-tips. Where root-hairs are not developed, the function of absorption is carried on by the epidermal cells found near the root-

ip. Root-hairs are merely the cylindrical protrusions of he superficial cells and they are formed, because they ause an increase in the area of the surface for absorp- ion. In a pea plant the formation of root-hairs is said o increase the surface of absorption twelve-fold.

Since the amount of water that a plant needs is very :onsiderable, there should always be a large number of oot-hairs in a plant. It is true that root-hairs are :phemeral structures inasmuch as the life of a root-hair is matter of a day or two. But every root of a plant bears root-hairs throughout its life, and the root-hair region in a growing root would be found to be *more or less constant in* its extent, although its position is found to be advancing forward with the growth of the root-tip. Just behind the elongating region new root-hairs are formed to replace those that are shrivelling and dying behind. In other words, every day as many root-hairs are formed in front of the root-hair region, as wither up behind this region. In addition to this roots produce lateral branches, thus leading to the increase in the number of root-hairs.

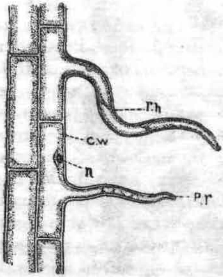
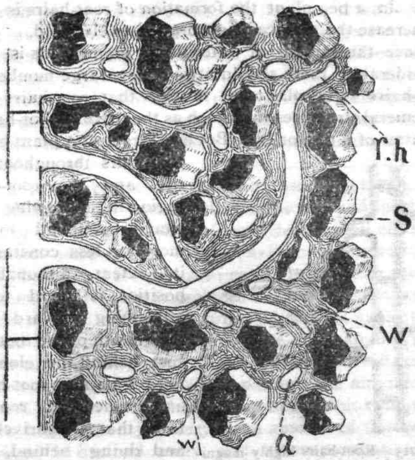


Fig. 215.—Root-hairs highly magnified. (Diagammatic) r.h, root-hair; c.w, cell wall; n, nucleus; p.r, protoplasm.

A root-hair being a cell *containing protoplasm*, absorption of water must be its essential feature. It consists of a cell wall of cellulose enclosing protoplasm containing vacuoles. Every root-hair grows in between the soil particles and becomes attached to them. So,

between the film of water adhering to the soil particle and the water in the vacuole of the protoplasm, there is a distinct membrane consisting of the cell wall and the



'ig. 216.—Root-hairs and soil particles. r.h, root-hair; s, soil particle; w, water; a, air space.

›rotoplasm. The condition of the cell sap and the for-es at work are such that water goes into the interior of he root-hair, but water does not get out from inside the oot-hair.

For a clear grasp of how this one-sided passage of 'ater is brought about in a plant, it is necessary to nderstand the behaviour of solutions in water, with ·ference to one another and also to membranes they

come in contact with. We know that when two solutions of unequal density are brought together, diffusion takes place slowly. For instance, into a tall jar filled with water, if a solution of potassium bichromate is poured, through a thistle funnel tube so as to form a layer at the bottom and left for itself, the bichromate of potassium will diffuse into the water slowly and this process will go on, until the whole of the water becomes uniformly yellow. If, instead of bringing together the surfaces of water and potassium bichromate directly into contact, a membrane, such as a piece of parchment, is interposed even then diffusion will go on. When a tube of parchment filled with a solution of common salt or potassium bichromate is placed in water diffusion commences. The solute potassium bichromate or the common salt passes from the tube out into the water, while water gets into the interior of the tube with greater rapidity than the salt. If sufficient time is allowed, the solution inside the tube and the water outside become equalised in strength. If parchment is used it appears to be permeable to diffusible substances, such as salt, sugar and potassium nitrate indiscriminately. When a membrane consisting of collodion or precipitation-membrane is used, we find that it is permeable fully only to water, but not so to every other substance. In other words, these membranes are semi-permeable.

If a thistle funnel tube to whose mouth a membrane of collodion is tied be filled with a weak solution of tannin and, then, lowered into a beaker containing a weak solution of iron sulphate, the colourless solution in the thistle tube gradually becomes black, whilst the liquid in the beaker remains quite clear. On reversing the arrangement the water outside becomes black, but not the water inside the tube. From this it is clear that tannin does

not pass through the membrane of collodion, althoug water and iron salts do. That a precipitation membrar is also semi-permeable can be easily demonstrated. Th membrane being a delicate one it must have a suppor Prepare two tubes of parchment and fill both the tube with a weak solution (1 per cent) of calcium nitrat Immerse one tube in pure water and the other in weak solution of di-sodic phosphate. Add a littl methylene blue to the liquid within the tubes. After day methylene blue is seen in the water, but not in th solution of disodic-phosphate. This is because a preci pitation membrane of calcium phosphate is formed clos to the parchment inside the tube, which is impermeabl to a solution of methylene blue. By using potassiur ferro-cyanide and copper sulphate solutions, a mem brane of ferro-cyanide of copper is formed which is als semi-permeable.

In the case of root-hairs, and for that matter all livin cells also, the cellulose cell wall is permeable to wate as well as other salts, but the protoplasmic layer be haves as a semi-permeable membrane. This can b demonstrated, by immersing bits of tissues whose cell have coloured cell sap in solutions of potassium nitrat varying in strength from 3 to 5 percent. Staminal hair of *Cyanotis*, bits of beet-root, or scrapings from blu violet, or red petals serve this purpose very well. Whe any one of these are placed in salt or potassium nitrat solution, certain changes are observed in the cells. A soon as the salt solution passes into the cell, the proto plasm shrinks to a slight extent at first, leaving som space between it and the cell wall. This space increase gradually and the protoplasm shrinks more and mor The coloured sap is confined to the vacuole within th protoplasm. Since fluids are incompressible it follow

that the addition of salt solution has caused some of the water of the cell sap to pass out from the vacuole, but none of the dissolved pigment to which the cell sap owes its colour has escaped from the vacuole. Thus it is clear that the cell wall is permeable, whilst the protoplasmic membrane is semi-permeable. The passage of water outwards from within the vacuole, through the protoplasmic layer, is caused by the salt in the water outside. The presence of the solutes in the cell sap of cells will also cause water to move into the cell sap contained in the vacuole through the protoplasm. Of course some of the salts dissolved in water may also pass in through the protoplasmic layer.

Within the living cells of plants are formed various solutes, among which sugars are prominent, and to which the protoplasmic membranes bounding the vacuoles appear to be practically impermeable. These solutes are known as **osmotic** substances. The processes of absorption and movement of water within the plant depend on the passage of water through membranes on the other side of which solutes exist, in accordance with the universal tendency to establish equilibrium.

Just like other cells, root-hairs contain in their cell sap solutes which are osmotic. The osmotic pressure of the cell sap increases with its concentration. Water in the soil must pass through the cell wall and the protoplasmic layer of the root-hair and get into the vacuole on account of the presence of solutes in the cell sap. This process of the passage of a solvent through a semi-permeable membrane which will not allow the solute to pass out is called **osmosis**. As water gets into the root-hair, a certain amount of pressure is exerted on the wall of the membrane and this pressure makes the root-hair turgid. We should be careful to distinguish

between osmotic pressure and the pressure of water causing turgidity.

Now we are in a position to realise the importance to the plant of this property of semi-permeability of the layer of protoplasm enclosing the vacuole. If the protoplasm were to be as permeable as the cell-wall to all the substances, there would be a constant osmotic leakage of osmotic substances from the root-hairs and cells of plants into the soil and absorption of water would not be possible.

The soil water in which various salts are in solution passes into the root-hairs, because of the presence of osmotically active substances within the protoplasmic film. The water thus absorbed from the soil by the root-hairs passes slowly from cell to cell into the cortex which serves the young root as a temporary reservoir The passage of water from the root-hair into the adjoining parenchymatous cells of the cortex is in accodance with the ordinary laws of osmosis. As absorption is going on continuously, all the cells of the cortex become turgid and the internal pressure becomes great.

The endodermis appears to be of great use in facilitating the passage of water from the cortex into the stele by preventing water from passing laterally. This layer is particularly well developed in roots and the suberisation of the lateral walls of the cells render these walls impervious to water.

The water passing into the stele under the control of the protoplasm gets in to the vessels and tracheids of the xylem. The movement of water through the conducting tissue of the plant is very rapid. Water passes from the xylem of the root to the xylem of the stem, as the xylem of both are continuous. From the stem water finds its way into the leaves through the veins. Almost all th

water that is absorbed by the roots passes in to the leaves. Of all the organs of the plant it is the leaf that needs water in large quantities. The fine net-work of veins, besides forming a very efficient frame work to keep in position the mesophyll cells of the leaf, is also useful in carrying water to every nook and corner of the leaf, so that all the cells of the mesophyll may draw water. Further the cells of the bundle sheaths connected with the veins take in the water from the veins very readily to deliver it to the palisade and spongy parenchyma. They are also useful in helping the transfer of food-materials from parenchyma to sieve-tubes.

That water passes in the stem, leaves and the roots, only through the xylem can be easily demonstrated. Place a fairly well developed seedling of any plant or leafy branches in water, coloured red with eosin, and after an hour or two examine transverse sections of the stem and the root. In the stem the xylem alone will be red, whereas in the root all the parts, root-hairs, cortex and the xylem will be stained red.

In the stem the xylem through which water passes is traversing the stem nearer the periphery than the centre of the stem. This is the case even in stout branches in which a considerable amount of wood is present, because water passes only through recently formed xylem, and not through old wood. So there is the danger of some of this water moving through the xylem being lost by evaporation. But this is very effectively prevented in all young stems by the epidermis. In the roots the exodermis and the endodermis are also useful in this connection. As more water passes through the xylem of older stems and as the epidermis becomes torn, a more effective protection is required, and, therefore, we find cork in older stems taking the place of the epidermis. Besides

forming a very efficient water-proof covering, cork affords protection against the bad effects that may result when sudden changes of temperature occur, because it is a very bad conductor. The importance of cork as a water-proofing material can be realized by the fact that a potato deprived of its cork covering loses in two days sixty times as much water as an unpeeled one of equal weight.

The conducting tissue or xylem which the water absorbed by the root-hairs has to traverse in a small plant is not very extensive in length; but in the case of tall trees the transpiration stream or the water ascending in the xylem has to pass through a very long stretch of xylem to reach the leaves. In nature we see the transpiration stream reaching the leaves in trees which are as tall as 200 or 300 feet. But the forces giving rise to this transpiration stream are not yet fully determined. Although it is suggested that root pressure from below or a suction from above may cause the movement, there are valid objections to both.

Root-pressure cannot be considered to be the cause, because in many plants the root-pressure is very slight or absent. Further, when evaporation from the leaves is very great, root-pressure is very low and it is very high only when evaporation is lessened.

Evaporation of water from leaves, or transpiration as it is called, induces a suction undoubtedly. The atmospheric air surrounding the leaves of plants is generally not completely saturated. Therefore water must escape from the leaves into the atmosphere as vapour. That leaves lose water is obvious when they wilt. But they do not generally wilt while intact on the plant, because water is absorbed from below, almost equal in amount to the water transpiring from above. The cells in the leaves

that lie in contact with the atmospheric air give up some water and this results in the concentration of the cell sap, which means more osmotic pressure. Since these cells are connected internally with the mesophyll cells water will be sucked, as it were, from these cells by the former. This suction will be continued from cell to cell through the parenchyma and finally it reaches the xylem vessels. A cut branch placed in water is able to raise the water to its uppermost twigs. It is easy to prove that suction actually occurs in plants. Cut a vigorously transpiring branch and keep the cut end in water for some hours and then fit it to a long vertical glass tube filled with water by means of a rubber cork or tube. Close the other end with a finger and dip it in mercury contained in a vessel and withdraw the finger. Evaporation of water will go on from the leaves and the water within the tube will be absorbed. After sometime the mercury will rise within the tube to a considerable height.

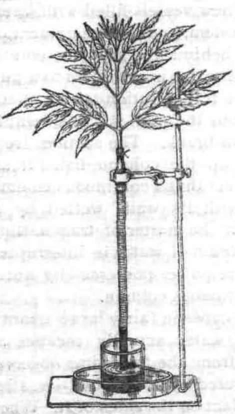


Fig. 217.—Apparatus to show the suction power of transpiration.

This suction which is caused by transpiration from leaves is transmitted to the cavities of vessels and

tracheids in the xylem. All these vessels are full of water, at any rate, when they are young. At first in a young seedling there would be continuous columns of water in each of the series of vessels, extending from the veins of the leaves, through the stem, to the root. As the seedling grows into a plant, new vessels filled with water are added in the root and the stem, by the development of rows of cells some distance behind the growing points. So this continuous column of water is subjected to a pull from above on account of the transpiration taking place from the leaves. Even when the pull is considerable the column of water does not break. The suction from above instead of breaking up the column hauls it up bodily. It is a well known fact that a continuous column of water in a closed tube with its walls wetted by it behaves like a rigid solid in the matter of transmitting tension. Even when the column of water is interrupted by bubbles of air the cohesive power possessed by water enables it to maintain a continuous column.

As already stated water escapes in fairly large quantities from the leaves. That water actually escapes as vapour has to be inferred from the following observations. If a leafy twig is covered by a cold bell-jar, after sometime drops of water collect on the sides of it. When a small piece of dry cobalt paper which is blue is laid on a leaf and covered by a piece of glass or mica, so as to protect it from being affected by the moisture in the atmosphere, the colour changes into red soon. This is due to vapour of water reaching the cobalt paper.

Leaves are so constructed as to facilitate the escape of water as vapour. The thinness, flatness, the arrangement of parenchyma, the presence of intercellular spaces and stomata in large numbers are favourable conditions for transpiration.

Since the epidermal cells are cutinised on the free surface evaporation is not likely to take place through the surface. The actual transpiring surface is the surface of the enormous number of internal cells, abutting on the intercellular spaces in the mesophyll of the leaf. As the air in contact with these cells is not saturated, imbibition water of the cell walls will escape into the spaces as vapour. This loss is immediately made good by withdrawal of water from the protoplasm, lying in contact with the cell wall on the inside. The protoplasm in its turn draws water from the vacuole. This movement of water from the interior of the cell to the intercellular space affects the cell by causing concentration in the cell sap. In consequence of this concentration of the cell sap, water will be drawn in by this cell from the adjoining cells which are not themselves transpiring. As this process passes from cell to cell, the loss of water is conducted from the superficial cells where evaporation is taking place into the depths of the tissue.

The amount of water transpired by the leaf surface of a plant during the day time is very considerable. A tall well grown sunflower plant is said to lose by transpiration about a litre of water in a day. A large tree must be losing by evaporation from the leaves in a dav about three to five hundred litres of water.

The amount of water escaping as vapour by transpiration from a plant can be determined easily by weighing the plants growing in pots. Before weighing they should be covered so as to prevent evaporation from the pots. The quantity of water transpired, however, depends upon various factors, such as the structure of the leaf, temperature and humidity or dryness of the air. Leaves possessing a large number of air spaces in the mesophyll are likely to lose large quantities of water. Dry air will

increase the amount of water transpired, whilst moisture in air retards the process considerably. High temperature and good diffused light are favourable to transpiration, but low temperature and darkness minimise the

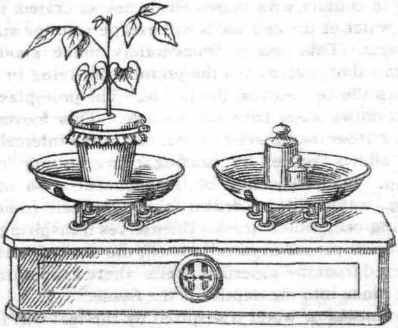


Fig. 218.—Apparatus to determine the amount of water transpired by a plant by weight.

loss. Leaves lose more water on a windy day than on a quiet calm day.

In a typical land plant stomata play a great part in transpiration and, as a matter of fact, stomatal transpiration only is of importance in this connection. It is only in plants inhabiting moist situations the cuticular transpiration becomes considerable. Though the openings of the stomata are extremely small, their distribution and presence in enormous numbers compensate for their minuteness. A sunflower leaf is said to have about thirteen million stomata.

The stomata play a very important part in the regulation of transpiration. They not only facilitate transpiration, but also can stop it. The guard cells of the stomata are capable of altering the width of the pore by their movements. The guard cells are fixed at their ends, their inner and outer walls being free. These cells contain chloroplasts and they are generally active. They react to the external conditions in a wonderful manner. When there is good illumination and the air is humid to a certain extent, the stomatal pore becomes widened. Under these factors the guard cells become turgid by absorbing more water and this causes the opening of the pore. Darkness and dry air leads to the diminution of turgor and hence lessening the width of the pore.

Transpiration from the leaves of branches cut off from the plant is usually determined indirectly by the use of a set of apparatus called **potometer.** The rate of transpiration from the leaves of a cut branch is more or less equal to the rate of absorption and, therefore, the amount of water absorbed may be taken as a measure of the loss of water by transpiration. There are several types of potometer but the one devised by Farmer is convenient to use. This consists of a wide-mouthed bottle fitted with a cork in which are bored three holes, the one intended for the cut branch being a little larger than the other two. The smaller holes are intended for the insertion of a thistle funnel tube with a stop-cock or a glass rod and a capillary tube bent at the two ends and provided with a scale. The branch intended for the potometer must be cut preferably under water and left in it over night. The fixing of the cut end of the branch to the rubber cork, and the insertion of the funnel-tube and the bent tube should be done under water.

The general arrangement may be inferred from the figure. All connections ought to be made water-tight by using wax or plasticine. After allowing a small bubble of air to get into the free end of the capillary tube, it is

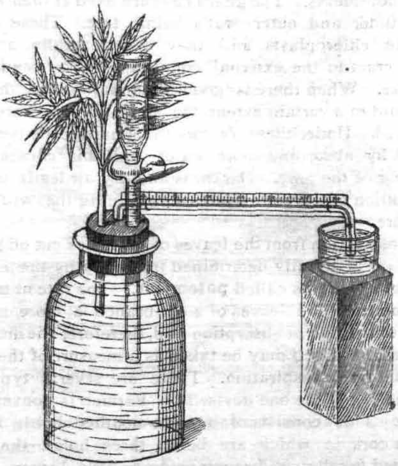
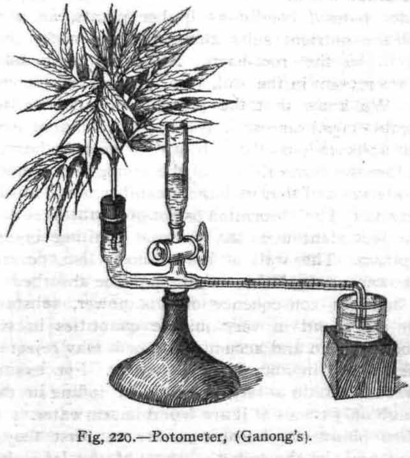


Fig. 219.—Potometer. (Farmer's).

dipped in water. This air bubble serves as an index to measure the amount of water absorbed. By manipulating the funnel-tube or the glass rod, the air bubble may be sent back and several readings may be taken. The potometer devised by Professor Ganong is also a very useful one, and it is easy to set up and can be got ready

within a very short time. The method of setting up and using this set of apparatus may be learnt from the illustration in fig. 220.



Fig, 220.—Potometer, (Ganong's).

Nutrient-salts and Water-culture:

The water absorbed by the root-hairs from the soil contains several soluble salts present in the soil. If we try to grow plants by giving them only distilled pure water, they do not thrive. On the other hand, they do well if river water or a watery extract of soil is used.

The water in the soil contains a number of mineral salts of which many are useful for plants, and the salts at the disposal of plants on the surface of the earth are

really unlimited. Water also is generally available over a large part of the surface of the earth. This accounts for the existence of green vegetation everywhere in the world.

Under natural conditions higher plants, as a rule, absorb the nutrient salts along with the water that is taken in by the root-hairs. Although many soluble salts are present in the soil, all of them do not enter the cells. We know that the protoplasm acts as a semi-permeable membrane and, therefore, we cannot expect all the salts to pass through it. It must be borne in mind that the permeability of the protoplasm is not the same always and that its impermeability is not absolute for any salt. The absorption or not of a substance seems to be dependent upon the external limiting layer of protoplasm. The wall of the vacuole also possesses this power of regulating what shall be absorbed and what not. In consequence of this power, substances which are found in very minute quantities in water may be taken in and accumulated, or it may reject substances found in abundance in water. For example, sea-weeds contain a large amount of iodine in them, although only traces of it are found in sea-water.

When plants are burnt in a fire, at first they get charred and, in the end, the whole of the lot is burnt away and there is left only some quantity of white ash. The conversion of the parts of plants into charcoal, while combustion is proceeding, is a sufficient proof that there is carbon in the body of a plant. Very nearly half the dry weight of a plant consists of carbon. This element forms not only a predominant one but also the most important element in all the compounds which build up the living organism, because the molecular combinations which carbon is capable of forming is

most varied. Since during the process of combustion of a plant water vapour, carbon dioxide, ammonia and a gas containing sulphur are given off, it is evident that water, carbon, nitrogen and sulphur besides the ash must form the constituents of the plant body.

The ash constituents contain mineral salts and the mineral salts present in plants are essential for the growth of the plant. From ash analysis we learn that the elements potassium, calcium, magnesium, phos- *phorus, sulphur, iron, silicon, chlorine and sodium* are universally present in plants, and, therefore, they are of general occurrance. At the same time, we must bear in mind, that because a substance is invariably present in a plant it does not necessarily follow that it is essential. What elements are essential and what are not can be determined only by experiment. Taking advantage of the fact that plants take in everything they need through the medium of water, plants may be grown in glass jars containing distilled water to which certain known salts are added, in some definite proportions. This method of rearing plants is called **water-culture.** Plants may also be grown in pure sand by watering them with the prepared solution. This is **sand-culture.**

For water-culture experiments seeds whose seedlings are capable of rapid growth, such as those of beans and maize, are germinated in sterilised moist sawdust or sand. When the radicle is well developed the seedling is fixed in the lid of the glass jar as shown in fig 221. For success in water-culture experiments the jars must be thoroughly rinsed with dilute nitric acid first, and then with an aqueous solution of corrosive sublimate. By repeated washings with boiled distilled water all traces of corrosive sublimate should be removed, as this substance is a deadly poison.

There are many kinds of solutions used for water culture, but the simplest and the one giving good results is that known as Von Crone's solution. This consists of 1 or 2 litres of water, potassium nitrate 1 gramme, calcium sulphate 0.25 gramme, magnesium sulphate, 0.25 gramme and ferrous phosphate 0. 5 gramme.

For fixing the seedling in the lid of the jar it is best to use asbestos wool sterilised by burning it in the flame

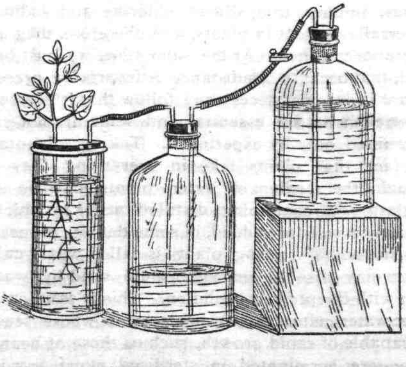


Fig. 221.—Apparatus for aerating water culture jars.

of a spirit lamp or gas burner. As the culture solution can keep in solution only a small amount of oxygen, it is necessary to force air into the culture solution in the jar, at least once a day for fifteen minutes in the form of small bubbles so as not to cause any damage to the roots. A very simple and convenient method of forcing air into the culture solution is shown in fig. 221.

The salts used in culture solutions consist of the elements **nitrogen, sulphur, phosphorus, potassium, magnesium, calcium** and **iron.** All these seven elements and the three elements **hydrogen,**

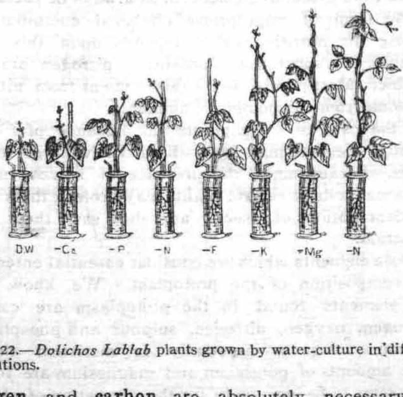


Fig. 222.—*Dolichos Lablab* plants grown by water-culture in different solutions.

oxygen and **carbon** are absolutely necessary for the growth of plants. Hence these ten elements must be considered as the **essential elements** for the growth of plants. Plants can grow to maturity, flower and set good seed only if they are supplied with salts composed of the seven essential elements mentioned above. If the culture solution is defective in any one of these elements, plants do not grow well. For instance, if in the culture solution ferrous phosphate is omitted

and calcium or potassium phosphate is added instead the element iron will not be available. A plant grown in a solution wanting in iron would have pale yellow leaves instead of green leaves. The results of the growth of plants in defective solutions may be inferred from fig. 222.

The amount of salts needed is indeed very small. Further, the essential elements must always be presented in the form of appropriate chemical combinations, because the nutritive value depends upon this. For example, all substances containing nitrogen are not suitable. Most plants obtain this element from nitrates and some from compounds of ammonia.

In the case of some plants the presence of a non-essential element may be a distinct advantage to the plants. For example, the presence of silicon in the epidermal cells of certain plants may protect them from the depredations of insects, and thus save them from extinction.

Those elements which we consider essential enter into the composition of the protoplast. We know that the elements found in the protoplasm are carbon hydrogen, oxygen, nitrogen, sulphur and phosphorus. In young organs, especially in meristem tissues large amounts of potassium and magnesium are found. Iron seems to be necessary for the formation of chloroplasts. Magnesium also is essential for chloroplasts. Calcium, though not present in protoplasm, occurs in certain layers of the cell walls. It seems to be useful in connexion with metabolism. By combining with oxalic acid and forming calcium oxalate, it prevents the injurious effects of the oxalic acid and it is also said that in some way it is useful in connexion with the transport of plastic carbohydrates. Salts, both organic and

inorganic are also useful in the maintenance of turgidity.

The profusion of vegetation on the surface of the earth is due to the fact that green plants utilize only such of the substances as are very widely distributed on the *surface of the earth. The ordinary salts found in the* soil contain the essential elements. At the same time plants do not use all the elements, though they are abundant and widely distributed. For example, the element sodium has a world-wide distribution and yet it is not an essential element. Sometimes plants accumulate in them large quantities of certain elements, even though such elements may be present, in such small quantities, that their presence could not be detected even by chemical tests. Certain sea-weeds, as already stated contain large quantities of iodine, although it is difficult to demonstrate its presence in sea-water.

CHAPTER XIV

PHOTOSYNTHESIS AND FOOD OF PLANTS

From water-culture experiments we have learnt that certain mineral substances are essential to plants, and also, that plants obtain all the elements required for their nutrition, excepting carbon, from the soil in the form of water and mineral salts. Although a small portion of the water containing mineral salts absorbed by the roots passes by osmosis from cell to cell, to meet the local needs, the bulk of it passes as transpiration stream to the leaves. From the leaves this water escapes as vapour leaving behind the mineral substances. The mesophyll cells of leaves thus receive constant supplies of mineral substances, and yet we do not find any accumulation of these substances in the leaves. So it is obvious that these mineral substances undergo chemical changes and become constituents of complex organic substances found in plants.

The absorption of water and transpiration from the leaves are only means to an end, the end being the manufacture of carbohydrates. The primary function of the leaf in undoubtedly the manufacture of carbohydrates. This process is termed **photosynthesis**. So the structure of the leaf is such as to facilitate photosynthesis in every way. One of the essential conditions for this synthetic work is the accession of carbon dioxide. The entrance of this gas into the leaves is chiefly through the stomatal openings. The epidermis being usually dry and also cuticularised it is impervious to this gas. When the stomata are open to facilitate the

passage of carbon dioxide into the mesophyll, there is nothing to prevent water from escaping as vapour through the same way. Transpiration is therefore an unavoidable accompaniment of photosynthesis, and this process of evaporation, though incidental instead of being primary, is useful, as it is an important factor in maintaining the transpiration stream which is necessary to supply water as well as salts to the chlorenchyma. *Another advantage of transpiration is the prevention* of injury from excessive heat to the plant by lowering the temperature.

Plants reared by the method of water-or sand-culture grow *well*, getting *the* required carbon *all right although* the culture solution contains no substance, containing the element carbon. So the only other possible source is the atmospheric air. While water and salts come from the soil, the gaseous substances, namely, oxygen and carbon dioxide are obtained by the plant from the atmosphere. We have sufficient reasons to infer that the manufacture of carbon-containing substances occurs mostly in the leaves of plants.

The only gases that are necessary to the plant are oxygen and carbon dioxide. That oxygen is essential for all vital functions is easily understood, but not the necessity for carbon dioxide. Since carbon forms, about half of the solid constituents of plants, and since the formation of other organic substances also are dependent upon this process this gas is indispensable to the plant. We know that carbon dioxide is present in the air in the proportion of 3 parts in 10,000 parts. When air containing carbon dioxide is supplied to a green plant exposed to good light under a glass case the amount of carbon dioxide in the air diminishes or the whole of it disappears. A plant having a supply of air freed

from carbon dioxide does not grow. So we have to conclude that the only source from which plants obtain the carbon they need is the carbon dioxide of the air. The proportion of this gas in the atmospheric air being so small, it may be thought that the supply is inadequate. But, when we consider the actual quantity available in the vast ocean of air, it is really enormous. Further, every plant that burns, every bit of fuel that is burnt, every organic substance that is undergoing decay and every organism that breathes produce carbon dioxide and thus augment the amount of this gas in the atmosphere.

Both oxygen and carbon dioxide may enter the plant by the epidermis or stomata. These gases can pass into the epidermal cells only if their walls are moist with water, but not when dry. Since the epidermis of most plants becomes cutinised, the only way by which these gases can reach the interior of the mesophyll is through the stomata. To ensure a constant supply of oxygen and carbon dioxide plants develop in their bodies a regular aerating system. The stomata in the epidermis, the lenticels occurring in the older parts of stems and roots, and the most irregular and extensive intercellular spaces found in the parenchyma of plants constitute the aerating system. The supply of oxygen to all the meristematic cells being very essential, intercellular spaces develop even amidst the cells in the growing point. These spaces are indispensable, because by mere diffusion from cell to cell oxygen cannot be expected to reach the places quickly where it is needed. Intercellular spaces being in communication with the exterior, air will get in quickly and occupy these spaces, and from here cells can get the oxygen easily, as it is near at hand.

The gas carbon dioxide in the air enters the stomata

and gets into the cavities existing below every stoma. These air cavities communicate with the air spaces in the spongy parenchyma. Even in the palisade parenchyma there are numerous small intercellular spaces. In fact, intercellular spaces are abundant in parenchyma wherever it may be found. So the intercellular spaces in the leaves become continuous with those in the stem.

The stomata are very minute pores and, therefore, it may be puzzling to think how these minute pores afford passage for a sufficient quantity of oxygen and carbon dioxide. But it is a demonstrated fact that air diffuses easily and quickly through a membrane drilled with minute holes, especially when these holes are elongated slits. Further, the stomatal pores are not really small relatively to the molecules of oxygen or carbon dioxide. Professor Ganong has pointed out that the capacity of the stomatal openings for the passage of gas is far in excess of that implied by their areas, and that an ordinary stoma when open, presents to a molecule of carbon dioxide or water an entrance or exit as great, as a passage seven miles wide appears to a man. Besides this the number of stomata present in the epidermis of a leaf is enormous. For example, in the leaf of the sunflower plant there are on the average, about 325 in the lower and 175 in the upper epidermis in one square millimeter of surface.

Other factors which influence the inflow or outflow of the gases are diffusibility and solubility of gases in water and their utilisation within the plant. The intercellular passages in the mesophyll of the leaves are in communication with the atmospheric air outside through the stomata and, therefore, all the intercellular spaces in the mesophyll of the leaves will be filled with the atmospheric air. But the composition of the air in

the intercellular passages is bound to be modified constantly, because *there will be an interchange of gases* between the cells and the air in the intercellular spaces. Carbon dioxide in this air will get into the mesophyll cells and this must cause a lowering of the pressure in the intercellular spaces of this gas. Consequently carbon dioxide will rush into the intercellular spaces from the air outside. Oxygen on the other hand will pass from the cell into the intercellular spaces thereby increasing the pressure of this gas in these spaces. So oxygen will move from the intercellular spaces to the air outside through the stomata. The air in the intercellular spaces being less saturated than the cells with water, water-vapour diffuses into these spaces from the cells and from thence it passes out into the atmospheric air, which is drier than the air inside the leaves. Thus we see that the direction of the passage of gases depends mainly on pressure, and in plants there will always be difference between the air inside and outside the leaves, inasmuch as the gas carbon dioxide is used up and oxygen is liberated, and further their solubility and powers of diffusion are also different. Carbon *dioxide is far more soluble in water than oxygen.*

From the study of germination of seeds we know that an embryo gets its food from the cotyledons or the endosperm, until the embryo developes into a seedling. As soon as green leaves are formed, the seedling needs no reserve food, as it is able to manufacture its food. If so we should be able to detect the food substances within the plant. By the use of an aqueous solution of potassium iodide and iodine the presence of starch in leaves may be demonstrated easily. If the leaves of a plant growing in the open be detached towards the evening before sunset from the plant,placed in alcohol after killing

them by immersion in boiling water and, then, immersed in an aqueous solution of iodine, they become blue-black, showing the presence of large quantities of starch. In the leaves of plants kept in darkness for a day or two and treated as above, we do not find any starch. When a starch-free leaf detached from a plant kept in the dark is placed in a vessel of water and exposed to sunlight starch makes its appearance in the leaf. In the same plant, if a leaf is exposed to sunlight for a few hours, after covering it with a stencilled tin foil or stout black paper and, then, if the same leaf is tested for starch in the usual manner, the letter stencilled appears black and the parts covered by the tin foil or paper remains white. We have, therefore, to infer that leaves are able to manufacture starch only when they are exposed to light, and only in parts of leaves actually illuminated by the rays of light.

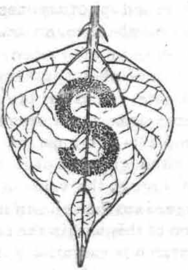


Fig. 223.—Leaflet of *Dolichos Lablab*. The leaf was covered with a stencilled plate and exposed to light for a few hours and then treated with iodine solution.

Starch is an organic compound having as its constituent elements carbon, hydrogen, and oxygen. Leaves always contain plenty of water, and this consists of the elements hydrogen and oxygen. Carbon dioxide gets into the leaves and reaches the interior of the cells, as it is a very soluble gas. Thus the constituent elements of starch and sugar namely carbon, hydrogen and oxygen are found in these substances, namely, water and carbon

dioxide, which are always present in the cells of the chlorenchyma. The chloroplasts in the mesophyll cells prepare the carbohydrate material by combining the constituent elements, after separating them from the compound substances. This process of synthetic work going on in the leaves is called **photosynthesis**, because it is one of combining simple elements into a compound, and this is possible only in the presence of sunlight. The first visible product of photosynthesis is starch, and small starch grains are found within the chloroplasts. However, in green plants sugar seems to be formed at first in the chloroplasts and most of this sugar passes into the cell sap, although some of it may pass on to other parts of plants through the veins of the leaves. This passage of the sugar into the cell sap must necessarily lead to concentration of this within the cells. Transformation of sugar into starch is essential if this accumulation of sugar in the cell sap is to be prevented. Concentrations beyond a certain point affects the activity of chloroplasts. Starch does not in any way interfere with the osmotic activity of the cells.

For the production of sugar the element carbon has to be dissociated from the element oxygen, and the energy required for this work is very great. It is about what is expressed by the temperature 1300 degrees centigrade. We know that neither sugar nor starch can be manufactured by the chloroplasts if sunlight is not available. So it is evident that the source of energy is sunlight. However, it should be borne in mind that ordinary sunlight is unable to decompose carbon dioxide or water, and were it possible we should not expect to find carbon dioxide or water vapour in the atmospheric air. Light is absorbed and it is converted probably into electric energy which is made use of for photosynthetic work.

When an alcoholic extract of chlorophyll is interposed between the light and the spectroscope, the spectrum shows very dark bands in red and orange and hazy weaker bands in the blue. From this it has to be inferred that the chloroplasts make use of the radiant energy represented by the rays absorbed. That these rays are actually made use of by chloroplasts in photosynthesis can be easily demonstrated. When a plant from whose leaves starch has been depleted, by keeping it in the dark for sometime, is exposed to red or white light, plenty of starch is found in the leaves, while under green light no starch is formed. A certain amount of starch occurs under blue light. A very ingenious method of proving that photosynthesis takes place very rapidly when plants are exposed to red light, and that the process is slow under other colours of the spectrum has been introduced by Englemann. Taking advantage of the fact that evolution of oxygen is an accompaniment of photosynthesis, he mounted a thread of an alga in water and exposed it to the solar spectrum, so that different parts of the green algal thread are illuminated by different coloured rays. A culture of the bacterium, *Bacterium termo* which is very sensitive to oxygen was introduced very close to the thread of alga. Largest number of the bacteria were seen crowded close to the part of the thread which was illuminated by the red rays of the spectrum. This means oxygen appeared more in this part than in any other part. That is to say, photosynthesis is most active in the part receiving red rays.

When chloroplasts are illuminated, they absorb the rays of the spectrum corresponding to the bands of absorption of chlorophyll. This radiant energy, after becoming transformed into electrical energy, is used in

splitting up the molecules of carbon dioxide and, thei combining them with the elements of water to fori sugar, oxygen being liberated at the sametime. Th exact details of the process of photosynthesis are n(clearly known. But the hypothesis advanced by som is that carbon dioxide is first reduced to formic acid an this later into formaldehyde. From formaldehyc glucose sugar is formed by condensation.

All these details are shown below by means of chem cal equations:—

$$\left.\begin{array}{c} CO_2 + H_2O \\ \text{or} \\ OH.COOH \end{array}\right\} = \underset{\text{(Formic acid)}}{H.COOH} + O$$

(Carbonic acid)

$$H.COOH = \underset{\text{(Formaldehyde)}}{H.COH} + O$$

$$6\,(H.COH) = \underset{\text{(Grape sugar)}}{C_6 H_{12} O_6}$$

In most green plants, if not in all, the excess of suga after a certain degree of concentration is reached, converted into starch by condensation, and this forn small grains in the substance of the chloroplast. Th may be represented by a chemical equation thus:—

$$n\,(C_6 H_{12} O_6) = (C_6 H_{10} O_5)n \quad + n\,H_2O.$$

That oxygen is given off when photosynthesis is goir on can be demonstrated very easily. Fill a narrow gla jar or a test-tube with water and support it inverted ov a large glass jar, also filled with water and previous charged with carbon dioxide. Place a few vigoroı shoots of *Hydrilla or Vallisneria* in the larger jar ar just thrust the cut ends of these into the narrow jar test-tube so that they may project a little into the jar test-tube and keep the apparatus in good diffused su light for some hours. Note the evolution of bubbles an

when sufficient gas has been collected, invert the narrow jar by closing its mouth with a ground glass and introduce a red hot splinter into it. The flaming of the splinter shows that the gas evolved is oxygen.

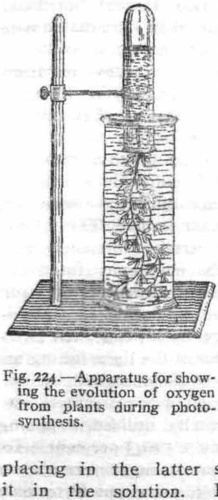


Fig. 224.—Apparatus for showing the evolution of oxygen from plants during photosynthesis.

The evolution of bubbles varies with the intensity of light. When exposed to bright sunlight, the number of bubbles given off is much less than in good diffused light. In shade and in dim light the number of bubbles is further reduced. In the dark there will be no bubbles.

Since the evolution of oxygen is an accompaniment of photosynthesis, it should also be affected by different colours of the solar spectrum. Take two large wide mouthed glass jars and partly fill one of them with a solution of potassium bichromate and the other with ammoniacal copper sulphate solution. Into each lower a narrow jar placing in the latter some weight so as to sink it in the solution. Introduce a healthy *Ottelia* or *Vallisneria* leaf into another small glass jar filled with water keeping the cut end of the petiole below water and place this jar within the second jar. Cover the mouth of the jars so as to exclude white light and leave the apparatus exposed to good diffused sunlight. Compare the rate of evolution of bubbles in

the two different lights, namely, orange and blue. Under the orange colour the bubbles come out as under diffused white light, but under the blue colour they come out very slowly and at long intervals, or they do not all come out.

Chloroplasts really perform two distinct functions, namely, the manufacture of sugar when illuminated and changing the sugar into starch, for which process illumination is not necessary. When living leaves free from starch are floated on sugar solution and left in the dark, starch makes its appearance in the leaves. Leucoplasts also change sugar into starch.

The amount of sugar formed by photosynthesis is dependent upon the supply of carbon dioxide and the intensity of light. Up to a certain limit the more the carbon dioxide the more is the sugar formed. The chloroplasts need only a light of certain intensity and there is a minimum and a maximum intensity. Too strong a light not only retards the formation of sugar, but may also injure the chloroplasts. Chloroplasts, however, avoid the injury by shifting their positions in the mesophyll cells. Out of the light falling on leaves only about 40 to 70 per cent is absorbed by the leaves, and only 10 to 20 per cent actually enters the chloroplasts, and the amount actually utilised in photosynthesis is still less, being only 0·5 to 3 per cent. To have a general idea of the amount of sugar formed we may say that one gramme of sugar is made by one square meter of leaf space, in one hour in diffused light.

The process of food-making is not completed with the formation of sugar. As protoplasm consists mostly of proteins, besides sugar nitrogenous organic substances also are needed in the nutrition of plants. Therefore, proteids also must be manufactured by plants. The

process of proteid synthesis is not restricted to any particular organ like photosynthesis. The presence of chloroplasts is not a necessary condition because plants without chloroplasts, such as fungi are able to manufacture proteids. It can take place in light as well as in darkness and possibly in any living cell. In spite of the fact that in any living cell this process can go on, there is every reason to think that most of this work is carried on in the leaves. Large quantities of the nitrogenous substances in the form of amides are found in mature leaves, especially when their activity is at its height, and this cannot be accounted for except by thinking that it is made in the leaves.

For the elaboration of proteids, substances containing the elements carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus are needed. Inasmuch as sugar contains carbon, hydrogen and oxygen, it is evident that this substance can be utilised as a foundation, material in the process of proteid synthesis. The water which is absorbed by the roots and which reaches the mesophyll of the leaves contains salts such as nitrates, sulphates and phosphates. Since amides make their appearance in leaves we have to suppose that carbohydrates are converted into amides. Later on amides become modified into several kinds of proteids by the incorporation of the elements sulphur and phosphorus contained in the sulphates and phosphates. The energy needed for the dissociation and combination of this proteid synthesis comes from chemical actions connected with respiration.

In this world the only place where organic matter is formed from simple inorganic substances is the green leaf. All organic matter existing in this world, however different they may be and wherever they be found must have been derived or formed from substances manu-

factured by the leaf. So nature's laboratory for the formation of organic matter is the chloroplast found in green plants. The life of the whole of the organic world is dependent on the process of photosynthesis. If there is no photosynthesis no animal can live. All the stored-up energy of this world is traceable directly or indirectly to this process.

Food of Plants

Both plants and animals use the same kind of material as food, but plants differ from animals in being able to make these substances from simple mineral substances. The food materials serve primarily for the construction of the new substance of the plant and for the growth of new cells. The nutritive material, it must be remembered, is useful to the plant only after it has undergone various chemical changes. The chemical changes occurring in plants constitute **metabolism**. Some of these changes tend towards increase of material and they constitute **constructive matabolism** or **anabolism.** In plants certain chemical processes involve the breaking down of materials contained in protoplasm, or the protoplasm itself. These necessarily lead to the loss of material and hence they are called **destructive metabolism** or **katabolism.**

Photosynthesis being a rapid process, large quantities of food material will be formed in plants. Since the quantity of material actually utilised by the plant for the formation of new tissues and in the repair of protoplasm is very small, accumulation of material is inevitable. The surplus food material is then stored for future use in various parts of the plant body. Any parenchymatous tissue may serve this purpose, and this tissue is abundant in both roots and stems. Reserve material

in the form of starch is present in the medulla, the xylem-parenchyma, the medullary rays and the rind of trees.

The storage of food material is undoubtedly of very great advantage to plants, because the demand for food is not the same at all times. Growing points which need material for their growth are far away from the place of storage or production. The photosynthetic activity, and the process of growth do not occur together. Sometimes the process of photosynthesis may be at a stand-still, and yet the need for food may be very great. For example, deciduous trees flushing forth in spring need large amounts of material for the formation of new leaves and branches. For the growth of these organs trees have to use the stored reserve material.

The reserve material consists of the three main types, namely, the carbohydrates, the fats and the nitrogenous substances.

Starch is undoubtedly the most common and one of the most important of the reserve materials in plants. We find starch grains in most parts of plants, and they are especially abundant in seeds, tubers and rhizomes. The food value of seeds, tubers, rhizomes and corms depends upon the amount of starch contained in them. Starch grains formed in the leaves are very small, but the grains of reserve starch are generally larger. As regards shape and size there is considerable variation. Reserve starch grains are striated, the laminations varying according to the plants. The starch grains in the seeds of *Dolichos Lablab* have concentric striations and they are eccentric in potato. (See fig 225.)

Just as starch grains found in chloroplasts are formed from sugar, so even reserve starch grains are formed from sugar, and leucoplasts are concerned in this transformation.

Although glucose and fructose are almost always found in living cells, they do not occur in large quantities. The only sugar that is found in large quantities as

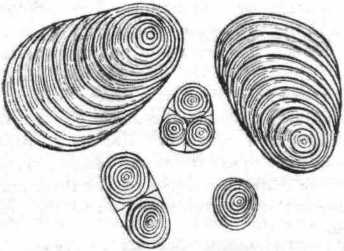


Fig. 225.—Starch grains of potato.

storage product is **cane-sugar** or **saccharose**. As examples we may mention sugarcane, the beetroot and some of the palms.

Reserve carbohydrate occurs as **hemicellulose** in the seeds of coffee and date palms. The excessive thickening of the cell walls of the endosperm in these seeds is due to the deposition of hemicellulose. In some plants of the Compositae the carbohydrate occurs as **inulin**. The bulbs of Jerusalem artichoke contain inulin.

In many seeds the reserve stuff takes the form of fat or oil, and these seeds are of very great economic importance. Oil exists in the form of very fine drops, diffused

in the protoplasm of the cells of endosperm or cotyledons.

Proteids occur in all seeds. In some they are in the form of amorphous particles or in the form of a network. Sometimes they assume regular shapes as in castor and gingelly seeds, and then they are called **aleurone grains.** In grains of cereal plants proteid exists as an aleurone layer just outside the endosperm. It must not be supposed that the different kinds of reserve material occur separately. They always occur associated together although one form may predominate.

As already remarked the reserve material is stored far away from the growing points and other younger parts in which growth is active. Carbohydrates and nitrogenous food material have to be translocated to places of storage from the places of production in the first instance and, then, later on from thence to the parts where growth is active. Generally food materials are stored in insoluble forms and as such they cannot pass from cell to cell. Therefore, they have to be rendered soluble before they could diffuse. This transformation of an insoluble substance into a soluble one and of an indiffusible one into a diffusible one is called digestion. The changes characteristic of digestion result in the breaking of compounds into simpler substances. The agents concerned in this process are enzymes, of which there are many in plants.

Starch has to be broken down in order to allow of its translocation and this change is brought about by the enzyme **diastase.** By hydrolysis caused by diastase, starch is converted into maltose according to the formula.

$$\underset{\text{starch}}{2\,(C_6H_{10}O_5)} + \underset{\text{water}}{H_2O} = \underset{\text{maltose or sucrose.}}{C_{12}H_{22}O_{11}}$$

Diastase is widely distributed in plants and it is found in the leaves, in germinating seeds and in other places where starch is stored. There seem to be two distinct kinds of diastase one corroding the grains in an irregular manner from outside, so that the grain loses its usual shape, and the other dissolving the grain evenly and uniformly, so that the shape is not affected, though there may be a decrease in size. **Invertase** is the enzme which changes the cane sugar into glucose and fructose. This is evident by the formulae :—

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + \underset{\text{water}}{H_2O} = \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose.}}{C_6H_{12}O_6}$$

Maltose is changed into glucose by **maltase** and the sugar inulin is converted into fructose by **inulase**. The enzyme that attacks hemicellulose and converts it into sugar is **cytase**.

Fats and oils get split into fatty acids and glycerine by **lipase**. **Tryptic** enzymes act on proteids in rendering them soluble.

All the food materials that are formed in the leaves are transported either to places where they are needed for use, or to places of storage. During the time much of carbohydrate material is manufactured in the leaves, as the photosynthetic process goes on actively. But during the night this process cannot go on. So if there is any translocation of carbohydrate from the leaves, we should expect to find less amount of starch in the leaves early before sunrise than what is found at evening before sunset. As a matter of fact a leaf plucked before sunset contains plenty of starch while a leaf detached before sunrise less, as may be demonstrated by placing these leaves in iodine solution after bleaching them with alcohol.

The carbohydrates and nitrogenous substances formed

n the cells of leaves diffuse into the parenchymatous :ells surrounding the veinlets. And from these they pass ›n to the veins through the veinlets. Since the veins oin the midrib of the leaf food material will pass :hrough the midrib into the petiole and thence into the ;tem. The fact that food materials actually pass through :he veins is easy to prove. If in a palmately lobed leaf we cut one of the main veins in the evening and detach the leaf in the morning and test it for starch we would find plenty of starch in the lobe into which the severed vein runs and in the other lobes the amount of starch would be very much less or there may be none.

As soon as the food material reaches the stem it may pass up, or down, or in both the directions. Since the food material travels through the veins of the leaves and then through the vascular bundles of the petiole and stem, it is obvious that it must travel through the xylem or phloem. We have evidence that the tracheal tissues of the xylem and the sieve-tubes of the phloem carry the food. The xylem vessels are particularly well adapted for a rapid movement of water, and so sugar, amides and proteids which are soluble in water can easily be transported through the xylem vessels. But the great portion of the food material passes through the phloem, and in fact it is the high-way for the vertical passage of food through the stem. The sieve-tubes contain plenty of carbohydrates proteids and amides. If the continuity of the phloem is wholly interrupted by girdling a stem all round, down to the wood, it will be seen that growth is slow or absent below the girdle. A cutting, with its bark completely girdled at the lower end, placed in water or soil produces adventitious roots in abundance above the decorticated portion and, in the part below, few or none appear. In the case

of plants having bicollateral vascular bundles, removal of the bark would interrupt only the external phloem, and the inner strands of the phloem would be intact and food would pass all right.

Besides the vertical transmission of food through the vascular bundles, there may also be *translocation* in the direction especially through the medullary rays. In this case the passage may be for storage or for the removal of stored food stuff. The intimate connection of the medullary rays with the cells of the xylem on one side and with those of the phloem on the other and their large number make them efficient organs, not only for storage but also for radial translocation.

CHAPTER XV

RESPIRATION IN PLANTS

ALL plants are continuously at work from the beginning of their life until their death. The performance of their vital functions is dependent upon a continuous supply of oxygen and, if this supply is cut off, all activities cease and unless oxygen is supplied within a reasonable time they die. This intimate relationship existing between the supply of oxygen and the vital functions gives us a clue to the source of energy which plants need for performing their work. Although large quantities of the organic material produced by higher plants are used for construction of new cells and storage, a portion of this material is broken down into simpler organic compounds. This process of decomposition is called respiration, and with it is always associated the *absorption of oxygen. In respiration carbon dioxide is* produced as well as some amount of water. But this is not of any importance to the plant. The breaking down of organic substances liberates some energy and this is the energy which plants make use of for their vital functions. Since the driving power in many of the vital phenomena of plants is dependent upon this liberated energy, *respiration is essentially an energy-releasing* process going on continuously in plants.

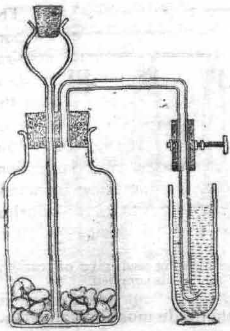
During respiration considerable quantities of carbon dioxide are given off by the plant and it is obvious that the carbon contained in this carbon dioxide should have come from inside the plant. This being so, respiration must lead to loss of weight, and this loss has to be made

good. We know that sugar is formed in plants and this is the basic substance utilised for all other organic substances. So we may consider this sugar to be the source of the respiratory carbon.

Since oxygen is absorbed during respiration it is commonly spoken of as a process of combustion. The absorption of oxygen and the production of carbon-dioxide and water as end products in both respiration and ordinary combustion lend support to this view. But the supply of pure oxygen does not lead to the acceleration of respiration, nor does the absence of oxygen immediately stop the process. So respiration eannot be considered to be a process of combustion. Further for pure oxidation high temperature is necessary and this does not exist in plants. In plants during respiration a certain amount of heat is produced. It is not perceptible because it is conducted away as soos as it is produced through the large extent of surface which plants possess. However, in parts of plants where growth is actively going on, there will be a distinct rise in temperature, if rapid conduction is prevented. Flowers of some species of Aroideæ show a rise of several degrees at the time of blossoming. The rise of temperature during respiration may be readily demonstrated in the case of flowers or germinating seeds. Fill two thermos-flasks, one with germinating seeds and the other with killed seeds. Insert thermometers so that their bulbs are in the midst of flowers or seeds. After some hours the thermometer will show a rise of 2 or 3 degrees.

Respiration in plants is easly demonstrated by showing that carbon dioxide is evolved by them. Place inside a wide mouthed bottle a few germinating seeds of *Dolichos Lablab* on pieces of wet blotting paper. Close the mouth of the bottle with a well-fitting rubber stopper

having two holes. Insert in one of the holes of the cork a thistle funnel-tube so that the end of the tube reaches almost the bottom of the bottle. Into the other hole is to be inserted a bent tube so that the end of the tube is on a level with the inner surface of the stopper. Close both the funnel and the free end of the bent tube so as to prevent the air from getting into the bottle. After the lapse of two or three hours connect the free end of the bent tube with another tube and dip it in a glass vessel containing lime water. Then pour water into the funnel to drive the air into the vessel of lime water. As the air bubbles through, the clear water begins to turn turbid and milky. If another set of apparatus prepared imilarly but containing dead seeds be tested no change vill be observed in the lime water.



'ig. 226.—Apparatus to demonstrate the evolution of CO_2 by germinating seeds.

This milkiness is due to the precipitation of chalk ormed by the combination of carbon dioxide with lime vater, and it is evident that the carbon dioxide has ome from germinating seeds.

That germinating seeds give out carbon dioxide even hen supplied with air freed from this gas can be easily emonstrated. Place some quantity of germinating seeds

of *Dolichos Lablab* in a glass jar or flask fitted with a rubber cork pierced by two holes and fitted with glass tubes. Connect the tube on one side with an aspirator interposing a jar or flask or wash-bottle containing

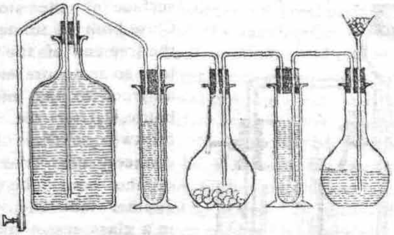
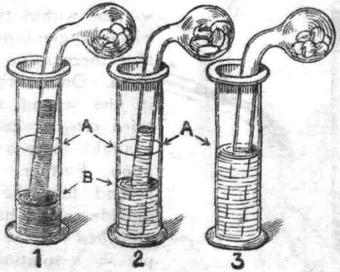


Fig. 227.—Apparatus to show that germinating seeds give off carbon-dioxide even when air deprived of this gas is supplied.

baryta or lime water. The other side must be connected with a jar or flask containing lime water and this with a flask having a strong solution of caustic potash and a thistle-tube fitted to its mouth containing pumice stones soaked in the same solution. All the connexions made by glass tubes and rubber stoppers must be made perfectly air tight. When water is allowed to flow from the aspirator bottle, air will be drawn in through the bottle containing potash and all the carbon dioxide in the air will be absorbed by the potash. The air thus deprived of the carbon dioxide will get into the flask containing germinating seeds. The lime or baryta water in the jar between the jar containing germinating seeds and the flask containing potash solution remains perfectly clear, whereas the lime-water i

the jar between the germinating seeds and the aspirator becomes milky. After a time the milkiness increases. It is needless to point out that the carbon dioxide has been evolved by the germinating seeds.

The absorption of oxygen during the respiratory process and its necessity to continue respiration are capable of easy demonstration. For this purpose soaked seeds of *Dolichos Lablab* are very useful. They germinate and



'ig. 228.—Apparatus to demonstrate that oxygen is used and carbon dioxide is evolved during respiration. Retort-like tube (1) with pyrogallic acid solution; (2) with caustic potash solution and (3) with water only. A, level of water at the beginning and B, at the close of the experiment.

evelop into seedlings only when oxygen is available, ut not when this gas is withheld. Secure three retortke tubes and three jars. Place five or six soaked seeds f *Dolichos Lablab* in the bulb of each of the three tubes rith some cotton or a few pieces of blotting paper ioistened with water, so as to keep the seeds moist nough to help germination. Fill the jars to about half ie first with a solution of pyrogallic acid and caustic

potash, the second with a solution of caustic potash and the third with pure water, and place the open ends of these tubes in these jars (see fig. 228) If the tubes containing seeds be examined next day, it would be found that the seeds in the third and the second tube have germinated, but not in the first. In the first tube all the oxygen has been absorbed by the pyrogallic acid and hence we see rise of the solution within the tube. Since oxygen is not available there is no germination. On the other hand in the second and the third jars, oxygen being available there is germination. Further, in the second tube the carbon dioxide evolved has been absorbed by the caustic potash solution and hence there is rise of water within the tube, whilst in the third tube there is no change as the space occupied by oxygen before the experiment has been occupied by the carbon dioxide.

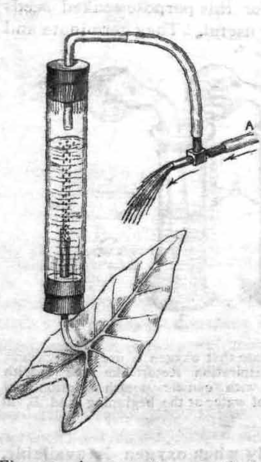


Fig. 229.—Apparatus to prove that air passes through the stomata.

In all higher plants the entrance of air into the plant is effected through the stomata. This fact admits of easy proof. That air actually passes out through the stomata can be demonstrated by dipping a leaf of castor in hot water with the lower side uppermost. When this is done

number of air bubbles rise from the lower surface of the leaf here and there. The air in the intercellular spaces expands on account of the heat communicated by the temperature of water and it escapes through the stomata. The passage of air from outside into the leaf through the stomata can be inferred from the following two experiments. Insert the petiole of a *Colocasia* leaf at one end of a cylindrical straight glass tube of about a foot

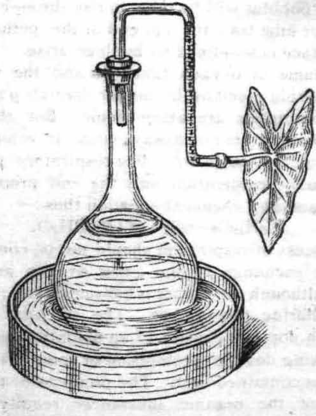


Fig. 230.– Apparatus to demonstrate the existence of stomata in the leaves of plants.

long and one inch in diameter fitted with single-holed rubber corks to both the ends, and after filling the tube with water to about nine inches insert a bent tube into

the upper cork (See fig. 229) and suck the air. Then a stream of bubbles rises from the cut end of the petiole. Instead of sucking the air, the tube may be connected with a suction tube attached to a water-tap and worked. Another method of showing the same is by using a flask into which the *Colocasia* leaf is fitted, after filling it with water and inserting the bent tube as shown in fig. 230. The flask containing the water is heated until the water just begins to boil and then it is cooled. At once a stream of bubbles will be seen to rise through the water in the bent tube from the cut end of the petiole. If the lower surface is vaselined no bubbles arise.

The volume of oxygen taken in and the volume of carbon dioxide given off by higher normal plants under normal conditions are about equal. But the carbon dioxide produced is not always equal in volume to the oxygen which dissappears. The respiratory process, if we take into consideration only the end products, may be expressed as a chemical equation thus:—

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O.$$

The process of respiration should not be considered to be a mere exchange of the gases oxygen and carbon dioxide, although the former is consumed and the latter is released during this process. The essential feature of respiration does not consist in an oxidation process but in a breaking down of protoplasm or some of the organic substances contained in it. The products of the decomposition of the organic substances readily take up oxygen. Respiration thus involves first the decomposition of complex organic substances and then the oxidation of these products resulting from the breaking down. In the process of respiration it is believed tha enzymes play a distinct part. A supply of oxygen i undoubtedly essential for the process, but it doe

aot combine directly with carbon compounds. Its chief ıse is to combine with and remove the substances formed ɔy the breaking down of protoplasm or proteins, so as to ɔrevent their accumulation. The presence of these ;econdary products may seriously interfere with the ɔrocess of respiration. So their removal is necessary to 'acilitate the continuance of the process until its com- ɔletion. The carbohydrates are mostly used up in the 'epair of proteins. It is also likely that in some cases ınd at times carbohydrates also may be utilised for the 'elease of energy by chemical decomposition, but even :hen not by direct oxidation.

The fact that plants continue to evolve carbon dioxide n the absence of oxygen is easy to prove in the case of ;erminating seeds. In water previously boiled and :ooled soak a few seeds of *Cicer* or *Pisum* for a few ıours. Peel off the seed-coats of these seeds carefully vithout injuring the embryo. Fill a narrow test-tube vith mercury and invert it in a small dish of mercury by :losing its mouth and clamp it to a stand. Pass three ır four peeled seeds of *Cicer* or *Pisum* into the test-tube :ontaining mercury without admitting air, and by means ıf a bent tube introduce a small quantity of boiled and :ooled water into the test-tube to keep the seeds moist.)bserve the tube for one or two days and note that it is bout half or one third full of gas. Pass into the test- ube some more water and a piece of caustic potash. \fter some time the mercury will rise to the top of the est-tube due to the absorption of carbon dioxide by the :austic potash.

In higher plants intramolecular respiration goes on vhen oxygen is not available, but this cannot supply he necessary energy to maintain life. Many bacteria, ungi and some algae flourish and respire even in the

absence of oxygen. In other words these are anaerobic. The yeast fungus is able to thrive as an anaerobic organism when there is abundance of sugar. The requisite energy is obtained by fermentation, which is the same as intramolecular respiration. In the absence of fermentable sugar yeast respires in the normal way by taking in oxygen. If both sugar and oxygen are available, fermentation as well as respiration goes or simultaneously.

In this universe no energy can be created anew o completely destroyed, but it may change its form. S the energy locked up in the food of plants must hav been stored by expenditure of energy. The carbo dioxide in the air is split inside the cells of a leaf withi the chloroplasts into carbon and oxygen by the energ supplied by sunlight. The oxygen escapes and th carbon combines with the elements of water and form a sugar. This is really transformation of the energy light which is kinetic, into latent energy in sugar. Th energy locked up in compounds is latent in the form unsatisfied chemical affinity, and when these are subje ted to the chemical processes constituting respiratio then kinetic energy is again given out and this is us by the plant for the performance of its vital functions.

Both plants and animals respire, and so we shou expect the carbon dioxide to accumulate in the atm phere. If this influx of carbon dioxide is not check it is obvious that the surface of our planet will so cease to have living organisms. But in nature, in sp of the universal katabolism going on in the form respiration, the atmosphere never becomes foul. T forces us to the conclusion that there must be so other process going on in nature which prevents accumulation of carbon dioxide in the atmosph

'lants having chloroplasts take up all the carbon, dioxide volve oxygen, as long as there is sunlight. The air endered foul by the breathing of plants and animals is hus made pure by green plants.

The process of photosynthesis carried on by green lants is to a certain extent antagonistic to the process f respiration. The former process takes place only luring the day time and only in green parts of plants, whereas the latter goes on always, both day and night and in protoplasm wherever it may be, and does not lepend upon the green colour. Respiration leads o loss of weight, but photosynthesis brings about an increase in weight; energy is released by the former and it is stored in latent form by the latter. Though the process of photosynthesis takes place only during the day time, it is at least twenty times more active than the respiratory process.

The part played by green plants is of the utmost importance in the economy of nature. The main work of a chlorophyll bearing plant is the continued transformation of the energy of sunlight into latent chemical energy. The chloroplastid is an apparatus imbedded in the protoplasm for catching the sun's rays. In fact the plant is a machine whose work is to store up large quantities of latent energy, by the absorption of sunlight. Thus we see that the source of energy is the sun. As already pointed out, the formation of starch from simple inorganic substances is the only way by which organic matter is formed upon our planet:--

"Nature does not possess any other laboratory for the formation of organic matter except the leaf, or more strictly the chloroplast." The energy thus stored up is released by the process of respiration.

CHAPTER XVI

GROWTH AND MOVEMENTS IN PLANTS

Plants manufacture large quantities of organic materials, and portions of which are transformed into constructive substances to be utilised in the formation of new cells and tissues. Both food-formation and growth take place in plants, but they may not go on at the same time and in the same place. As a matter of fact, we know that growth is actively going on in young parts of plants, whilst photosynthetic work and storage of material are the concern of the mature organs. Growth is localised at the free ends of leafy branches and roots. Once a plant begins its life, it goes on growing and living as long as favourable conditions continue. The same individual may continue to grow and exist for any length of time. But in nature we find some plants going through their whole development from the germination of the seed to the ripening of their seeds within a few months. After production of seeds they cease to live. Many plants which we call annuals are of this kind. The life of the annual is connected with the seasons of the year.

We have also trees which live for many years, and these, however, cannot continue to live for ever, apparently on account of the increased difficulty of exchange of materials between the roots and the leaves. Further, it is not always possible to avoid external disturbances. If the exchange of materials between the roots and the leaves be facilitated, then growth may go on indefinitely. Consider the case of a tree such as the banyan

which is capable of growing for a long time unceasingly and covering many acres of land by gradual extension if left undisturbed. The aerial roots penetrate the soil and facilitate not only the taking in of water and nutritive material and the exchange between the roots and the leaves, but also props up very efficiently the branches. (See fig. 29). As instances of banyan trees that have been in existence for a very long time we may mention two trees, one still growing in the neighbourhood of Madura town and the other near the village Jakkeri in Hosur Taluk, both in South India. A magnificent specimen of this tree possessing hundreds of aerial roots and covering several acres of land is still growing in the Sibpur Botanic Gardens near Calcutta. (See fig. 28).

The giant trees of California, namely *Sequoia gigantia* seem to grow tall and live for many years. A magnificent photograph of this tree was published by the National Geographical Magazine of California some years back calling the tree. "The oldest Living Thing". Some details about this tree was also given in the letterpress and it is as follows:—"Towering a giant among giants, the oldest living thing that connects the present with the dim past, majestic in its mien, its dignity and its world-old experience "The General Sherman tree" is the patriarch of the Sequoia National Park of California. It was already 200 years old when Christ was born . . . . The "General Sherman" was discovered in 1879 by James Wolverton, a hunter and named by him in honour of General William. T. Sherman. It towers 279.9 feet into the sky; its base circumference is 102.8; its greatest diameter 36. 5 and it has developed a diameter 17.7 feet at a point 100 feet above the ground."

Growth is essentially an increase in size caused by

change of form resulting from a re-distribution of material or by the addition of similar parts to the existing parts brought about by the use of fresh constructive material. Increase in size does not always mean increase in weight. A seedling though grown from a seed generally shows a loss of weight instead of gain.

By observing an young leafy branch we can easily find out how growth progresses in it. Growth may take place in any of the dimensions, but the most obvious growth is in the length. Every growing young branch terminates in a leafy bud consisting of a short axis with closely packed immature leaves. Immediately below the terminal bud we find the young leaves separated from one another by internodes of different lengths. The distribution of the growth in an young shoot can be studied, by marking the growing part with lines at equal intervals of a millimeter or one-sixteenth of an inch with water proof ink, and observing the same marks after a day or two. By close observation in the manner stated above we find that the greatest elongation takes place at some point below the tip. Above and below this portion elongation goes on diminishing, until it ceases above at tip and at a particular point at some distance below the elongating region.

The distribution of growth may be seen in the roots also. Compared with the stem, the region of most active growth is much shorter than in the stem. Select two or three seedlings of *Canavalia* or *Dolichos* with roots grown to about an inch long and mark the roots as indicated for the stem. Keep the seedlings on wet blotting paper between two glass plates and rest the plates against one edge of a tray containing some water, so that they are in a somewhat slanting position. After a day or two examine the roots and note where the elongation has

taken place. In the roots of *Cicer* and *Canavalia* the roots gave the following results when marks were made and observed :—

Canavalia seedling, marked into 8 divisions of one mm. each.

After 24 hours, no change in divisions 1, 2 and 4 ; 3, 5, 6 showed an elongation of 2mm, 7 was 3mm and 8, was 8 mm.

Cicer seedling, marked into 10 divisions of one mm. Each.

After 24 hours, 1 to 8 no change, 9 was 3mm and 10 was 7 mm.

After 48 hours, 1 to 8 no change 9 and 10 were respectively 5 and 15 mm.

In growing shoots the region of growth is longer than in the root. Even the growing portions are not elongating uniformly but are composed of zones passing gradually into one another, in which the rates of growth differ. In the shoots of some plants intercalary growth is a common feature. For example, in grass stems the portion of the internode just above the node keeps on growing long after the upper portion has become permanent and has ceased to elongate.

The elongation taking place in parts of plants depends upon the growth of the individual cells composing it. There are three phases in growth, namely the formation of cells by cell division, increase in their dimensions and changes in the cell wall or differentiation. The extreme tips of the growing point consists of embryonic cells endowed with the power of constant cell division. Just a little below this the cells begin to grow in size especially in the longitudinal direction parallel to the axis. Below this region changes in the cell walls take place. It should not be supposed that these three phases

of growth are restricted to definite regions. One region passes into the other insensibly. Formation of new cells by cell division is the most prominent feature of the *extreme tip and in the part below elongation* is the chief feature, though differentiation may be going on here and there in certain cells.

Embryonic parts:—In the embryo plant, while within the seed, all the cells are in the embryonic stage. As germination progresses only those cells at the extreme end of the plumule and the radicle remain in the formative phase, whilst the cells between these grow larger and longer. Therefore, in a higher plant the growing points of stems and roots alone consist of embryonic cells. The embryonic cells constitute the meristematic tissue. As a rule the growing points of the shoot system arise directly from pre-existing growing points. Occasionally, however, growing points may arise from permanent tissue as adventitious structures from callus or ordinary parenchyma. In the case of the root-system the growing points of the lateral roots arise from the pericycle and not from the growing point of the mother-root. Sometimes when the plumule is injured at its tip so that the growing point is lost, then a new growing point may develope from the meristem above the youngest leaf-primordium.

All parts of the shoot are formed in the meristem at the surface of the growing points, the first indication of such parts being a slight elevation of the surface. At certain definite points some cells in the meristem undergo division and are more active in growth than the others, thus causing slight swellings on the surface. These swellings gradually become more prominent and develop into distinct protuberances. Some of them develop into

leaves, whilst others remain small and become axillary buds. Since the organs of a shoot are superficial in origin they are said to be **exogenous**. In the case of the root the growing point being covered by the root-cap it cannot give rise to any lateral root on the surface at the root-tip. Lateral roots arise from the pericycle and come out through the cortex, and hence these are said to be **endogenous**. Adventitious growing points developing into shoots often arise endogenously on roots and shoots.

Elongation:—At the growing point whilst new cells are constantly produced, those already formed begin to change in size, shape and other characters. The most striking change in this phase of growth is the increase of size in a peculiar and economic way. The increase in size is usually a hundred fold or more, and it results chiefly from absorption of water from without. The meristematic cells at the growing point usually contain considerable amounts of water in the cell walls as imbibition water and in protoplasm also. More water is absorbed by these cells and they become turgid. The extra amount of water thus absorbed exerts pressure and extends the cell wall. The protoplasm inside the cell, which is ever active, adds some material to the cell wall so that it retains permanently the size it attains under pressure. This process of stretching of the cell wall and of addition of material leading to the further growth of the cell wall goes on until the cell attains its usual permanent form and maximum size.

No doubt the protoplasm also increases in quantity to a considerable extent, but much the greater part of the cell is occupied by water. As described above, water enters the cells because of the presence of osmotic substances, and makes them turgid. At first the minute

vacuoles are enlarged and, as absorption of water proceeds, these vacuoles become still larger and finally only one large vacuole may exist reducing the protoplasm to a primordial layer. It is indeed remarkable that plants attain the chief part of their enlargement, by means of water, thus dispensing with the necessity of using very large quantities of food substance which would be necessary, if the enlargement were to be brought about by increase in the amount of protoplasm. The cells in the embryonic stage have all the three dimensions more or less equal. Enlargement takes place in all directions, but not equally. Cells in some places may grow more rapidly in length than in their breadth, while others may increase more in the transverse direction. The process of elongation of any part is really the elongation of the cells constituting that part.

The growth and elongation of parts in plants is generally so slow that it is imperceptible. But in some plants growth is so rapid as to be visible even to the naked eye. The stamens of grasses grow very rapidly in length. For example, it has been observed that the stamens of wheat grow in length at the rate of 1.8 mm. per minute. When the aerial shoots of *Musa paradisiaca* are cut across, we see within five minutes the young leaf stalk and the convolute leaf blade rising above the level to about 1/5 to 1/4 inch, i. e., an elongation of about 1.2 mm. per minute. If the elongation of any part is carefully observed, it would be seen that the rate of growth in length is slow at first, then rapid until the maximum rate is reached, then slow and finally ceasing to grow.

The growth in length of any part of a plant may be found out by means of an instrument called auxanometer.

very simple form of this instrument is shown in fig. 231. he elongation is magnified many times and so it is asily observed. The long arm of the pulley should be at least twenty-five to thirty times the short arm. Then the rapidity of the growth would be magnified twenty-five to thirty times. By the use of an auxanometer we can measure only the total elongation. The manner of using this piece of apparatus may be inferred from the figure.

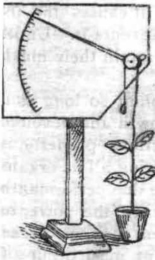


Fig. 231.—A simple auxanometer.

Conditions favouring growth:—During the formation of new cells by cell division a large amount of constructive material is used up and, therefore, an adequate supply of plastic material is necessary. For his constructive work energy is obtained from respiraion and so oxygen must be available, since in all higher plants respiration is possible only when this gas is present. In the neighbourhood of meristematic cells at the growing point, intercellular spaces exist which are connected with the spaces below and the lenticels, so that the outside air can freely find its way into these intercellular spaces. Embryonic cells must undergo transformation before they can function. The increase in size of these cells and turgidity both being caused by water, it is evident that an adequate supply of water is essential. Temperature within a certain range is conducive to growth. Higher temperatures above the maximum and below the minimum retard the growth. Light though essential for the well-being of the plant, inhibits growth, whilst darkness favours it. When dicoty-

ledonous plants are grown in darkness the stems become unusually elongated, white and soft. Leaves remain small, yellow and folded. Such plants are said to be **etiolated**. The influence of light seems to vary with the organs of plants. In some cases it causes the increase of growth, while in others it prevents it. Under light of moderate intensity leaves attain their maximum size.

Movements in plants:—Every plant so long as it is alive has to carry on metabolism, growth and development. If it is to perform all its functions properly, it must possess not only the power of placing all its organs in the position most appropriate for the due performance of their functions, but it should also have the power of responding in a suitable manner when changes occur. It is essential that the organs of a plant must occupy a position that is most advantageous for doing their functions, as otherwise living is impossible. So every plant must be able to shift its position either bodily, or to bring its organs into suitable positions. It is in virtue of the possession of this power that green unicellular plants and some of the algae move from a dark place to a lighted part. In the case of a higher plant, the foliage leaves must be so held as to enable all the leaves to obtain sufficient light, and the roots have to get into the soil and there branch in an adequate manner.

All movements in plants, resulting either in free locomotion of plants or in curvatures causing change of position in the organs of plants that are rooted to the soil, are due to the activity of protoplasm. We know that the most fundamental condition of life is the presence of living protoplasm. It is carrying on its activity by continual interaction with the factors amidst which it lives. Because of the presence of protoplasm

in a living condition, the living plants possess the special characteristics of **irritability** and power of **regulation.** Protoplasm reacts to the external factors in a peculiar manner. This property of protoplasm is called **irritability**. The peculiarity of the behaviour of protoplasm when it is stimulated by an external factor lies in the fact that the reaction observed is not the direct effect of an external cause but a very indirect result. Further, according to the condition of protoplasm the same factor may produce different effects. For instance the parts of a plant do not all respond to the stimulus of gravity in the same manner. Under this stimulus the main root of a plant goes vertically downward, whilst the main stem goes upward against gravitation.

The factors influencing the plant are gravity, light and moisture. In the case of lowly organised small green plants these external factors or stimuli play a very special part in giving a definite direction to movements of locomotion. For example, when a glass jar containing living algae such as *Volvox*, *Chlamydomonas*, and Desmids is exposed to one-sided illumination all the plants move towards the side lighted. Chloroplasts though embedded in protoplasm possess the power of shifting themselves to such a position that they can obtain the optimal amount of light. When the light is moderate the chloroplasts crowd together along the walls which are at right angles to the direction of the rays of light. They shift to the lateral walls and place themselves parallel to the cell wall as soon as the light becomes too intense, so as to avoid the destructive action of light. In darkness or weak light they arrange themselves parallel to the lateral and inner walls.

Presence of certain chemical substances even in very minute quantities may act as a stimulus. Bacteria and

certain algae are attracted by the presence of carboh drates and other nutritive substances. Certain organ acids being present in the archegonia, spermatozoi find their way to them. The presence of malic acid i the mucilage found in the neck of archegonia in Fern causes a large number of sperm-cells to crowd near th mouth of the archegonia. The sperm-cells of *Lycopodiun* mosses and liverworts are attracted by citric acid, sug and proteid substances respectively.

In plants, under normal conditions and when all th general conditions of vital phenomena are present, mov ments occur without any special stimulus. For examp the movement of the stem and the root in a straight lin and the unfolding of leaves in the leaf buds or flow buds caused by unequal growth are such movements, an these movements are called **autonomic** movements. we carefully observe the tips of organs they move abo all round the points of the compass. This is called **ci cumnutation**. The movement caused in the unfolding the leaves in a leaf bud is the result of unequal growt the inner surface growing more rapidly than the oute This is called **epinastic** movement. In Ferns the rolle condition of the circinate young leaf is due to th more rapid growth of cells of lower surface than th upper, and this is **hyponastic** movement.

Movements started by an external factor acting as stimulus are called **induced** or **paratonic** movement Under the stimulus of gravity, light and moisture, plant causes its organs to be brought into positior in which their functions can be best performe In other words, the significance of these paraton movements lies in the attainment of favourable cond tions of life. As already stated, the different organs a plant react differently to the same stimulus. Som

movements cause the organs to place themselves in particular directions with reference to the direction of the action of stimulus. Such movements as these are termed **tropisms**. If under the same circumstances, plant organs assume definite positions in relation to the plant *rather than to the direction of the stimulus, movements* causing such changes of position are called nastic movements.

The movements of orientation or tropisms, as they are called, are usualy distinguished as **geotropism, phototropism** or **heliotropism** and **hydrotropism** according to the *stimuli that are responsible for the movement.*

Ordinarily the main branches of trees and shrubs grow vertically upwards, while their lateral branches assume other positions. The main root of a plant goes vertically downward in response to the stimulus of gravity. For the tap-root this is the position of rest or equilibrium, and the same stimulus has a different *directive influence on the lateral roots.* They take a horizontal course. Any disturbance of equilibrium in the root, or in the shoot causes the part disturbed to make a curvature which will enable the part to assume its position of rest. That the vertical growth of the main root and main stem all over the world is due to gravity and that gravity acts differently on the stem and the root becomes clear if we bring a seedling to a horizontal position from its natural vertical position. When a seedling is treated thus the two ends of the axis of the seedling show curvatures, whilst the middle portion of the axis remains horizontal. The tap-root curves vertically downwards a little above the growing tip. This property of the root *to move downward* in response to the influence of gravity is called **positive geotropism**. As growth in length chiefly takes place

just behind the root-tip, curvature can be formed only in this region. It should also be remembered that the root-tip alone is sensitive to the stimulus of gravity. When the actual growing tip of the root is cut off no curvature is formed in the tap-root. However, as soon as a new growing point is formed the root responds. The stem also under similar circumstances responds by a curvature just behind the actual growing tip, but in a direction opposite to that taken by the root. Hence the shoot is said to be **negatively geotropic.**

By using the apparatus called the Klinostat we can demonstrate that the geotropic curvatures in roots and stems are really due to the stimulus of gravity. This apparatus is a clock-work arrangement which causes an axis to rotate. (see fig. 232.) After setting the Klinostat as shown in the figure, if we fix to the rotating plate, seedlings in different directions, no curvatures are seen either in the root or the shoot. This is because the seedlings are exposed on all sides equally to the influence of gravity. So there is no curvature. This method is adopted as it is impossible otherwise to prevent the action of gravitation.

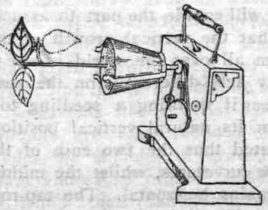


Fig. 232.—Klinostat.

As green plants require light for doing their work, we should expect them to respond to the stimulus of light also. When a plant is placed near a window, the shoot instead of growing erect in the open, invariably curves over towards it, because of the one-sided illumination.

Vhen a plant, fixed to the plate of a Klinostat otating horizontally, is placed near a window, the stem oes not curve towards the window, but grows erect. In iis case the plant receives equal illumination on all sides. . *Dolichos Lablab* seedling placed near a window howed the curvature within twenty minutes. Plants rowing in the open grow straight, for they are equally lluminated on all sides. In a shoot bending towards ight the axis lies in the direction of the rays of light, vhereas the leaves are either at right angles, or oblique. So the axis of the shoot is **positively heliotropic** or **phototropic** and the leaves are **transversely helio-tropic** or **diaphototropic.** This is another instance confirming the fact that the same stimulus acts differently on different organs of a plant.

Tendrils, aerial roots and normal soil roots of plants are negatively phototropic. Seedlings of mustard when grown in water, as in water culture experiments, are highly sensitive to light. The shoot is positively photo-trophic and the root is negatively so.

In the case of all curvatures the actual bending occurs only in the region of maximum elongation, but the power of perception of the stimulus belongs to the younger parts above or below this region.

The response of the root to the stimulus of moisture is called **hydrotropism.** The way in which the roots of the root-system of a plant grow in the soil is due to the stimuli of gravity and moisture. One may probably be led to wonder as to why the roots should be influenced in this manner by gravity and water. If we remember the functions that roots have to perform, it becomes obvious that it is necessary for the roots to be so affected by these two factors. The great need of the root-system is to explore the soil thoroughly and to come in contact

with as much soil as possible, in order to do its work efficiently.

The tap-root has generally a tendency to grow vertically downwards. But it will not do so under all circumstances. Sometimes, for the sake of moisture, it will move against the force of gravity. If in a large seedling-pan filled with sawdust or sand, we place in the centre a flower pot filled with water, and plant soaked seeds around it outside and allow them to sprout and develop into seedlings, we shall find all the roots turned towards the pot, containing water. Another way of demonstrating this is to allow seedlings to grow in a sieve and hang it in a slanting position, when all the root tips will be bent towards the side where there is moisture. In the case of epiphytes the aerial roots sometimes grow straight up for the sake of attaching themselves to branches lying above them.

CHAPTER XVII

ꝛEPRODUCTION, HEREDITY AND ORIGIN OF SPECIES

) far we have been dealing with the metabolic prosses of plants which mainly secure the maintenance of e plant as an individual. However much these prosses may favour individual growth and development, e plant as an individual cannot be expected to live for 'er. The conditions under which a plant is flourishing e of a fluctuating nature, and so it may die as the result an accident, or unfavourable external conditions. This ould mean a total extinction of plants. But plants, ɔwever, have another phase of life which brings into xistence a number of individuals. This phase of the lant is called Reproduction and it is not less important ıan Nutrition. Ordinarily in a plant reproduction takes lace long before the occurrence of its death. We know ıat in Angiosperms the obvious method of propagation by means of seeds which separate from the parent lant and then grow into new individuals. In the case f annuals the plant dries up only after the production f a fairly large number of seeds, which are really so ıany young plants in the embryonic stage and at rest. So, in Angiosperms, we clearly see a division of labour n the functions of nutrition and reproduction. The lower or a branch bearing sporophylls is the organ pecially intended for the reproductive process and ıutrition is the work of all the other parts of a plant.

In the case of flowering plants the obvious method of propagation is by means of seeds that are produced by

the sexual process. In plants the reproductive bodies are usually small in size compared with the vegetative organs. Consequently a plant is able to produce numerous reproductive bodies or seeds, thus fulfilling the object of reproduction. As already remarked elsewhere, an apparently prodigal production of seeds containing germs is a necessity.

The essential feature of sexual reproduction is the union of the sperm-cell with the egg-cell. Neither of these is capable of individual development. It is only after the fusion of the two sex-cells development is possible. Before fusion these sex-cells contain only half the number of chromosomes found in the somatic cells. So the cell resulting from the fusion contains as many chromosomes as there are in the somatic cells. The sex-cells before fusion are haploid and the oosperm or the fertilised egg-cell is diploid. Further, this fusion is also the cause of the mingling of the paternal and maternal characters. Since the sex-cells giving rise to the germ arise from two distinct sources,* the sexual mode of reproduction is also termed **digenetic** reproduction.

In the lower plants the oosperm surrounds itself with a cell wall and it germinates after a period of rest. But in the higher plants the oosperm begins to divide immediately. By frequent cell division and growth a multicellular embryo is formed. Forthwith this embryo continues its further growth and development in Bryophyta and Pteridophyta. But in Angiosperms all growth is stopped as soon as the seed is formed. Again growth is commenced after a period of rest, when the seed germinates.

Reproduction may be considered to be a phase of growth. In the case of the simplest lowly organised plants such as *Pleurococcus*, diatoms etc., reproduction

s merely a process of cell division. The single cell undergoes division. The two cells formed by cell division separate and become two distinct individuals. In more complex plants also vegetative growth often passes gradually into reproduction. For example, in the filamentous algae such as *Oscillatoria*, *Spirogyra* and others the filaments break up into bits, and these bits grow and become independent plants. Even in some Angiospermous aquatic plants branches get separated and each of them grows and becomes an independent plant. In all these plants it is the detachment from the parent that defines the individual. Besides these multicellular bodies, in many cryptogamic plants spores are formed, which bring about propagation. The spores are unicellular bodies.

Thus we see that plants have two distinct modes of reproduction. They are the **sexual** or **digenetic** reproduction and the **vegetative** or **monogenetic** reproduction. The special features of the former have already been dealt with. In the monogenetic reproduction single cells or multicellular bodies are formed from the ordinary somatic cells, and these grow into new independent individuals on their separation from the parent plant, either at once or after some rest. The cells in these bodies are diploid and not haploid.

In nature vegetative propagation is widely spread. This process is merely the separation of a part of the plant which becomes established as a separate individual quite independent of the parent physiologically. The separation of the part may be caused in various ways. It may be by the death of the parent, or due to the rupture, or death of tissues. Plants such as *Ipomoea reniformis* and *Centella asiatica* flourish everywhere. In all these plants branches creep along the surface of the

ground producing roots at the nodes. These plants may go on increasing by growth and establishing new colonies in any number and occupy within a short time considerable areas, because of the capacity of becoming independent plants possessed by the creeping branches, when they get severed from the older portions either by decay or accident.

By the independent establishment of axillary buds and when bits of ordinary branches are detached from the parent plant, new plants arise. In many aquatic plants such as *Ceratophyllum demersum*, *Utricularia flexuosa* and *Elodea canadensis* branches become separated and these become independent plants. In some of these plants the terminal buds detach themselves and sink to the bottom of the pond. Later on these grow and become independent plants. Plants such as *Convolvulus arvensis*, *Clerodendron phlomoides* and *Aristolochia bracteata* get propagated by very small bits of their stems. These plants have an extensive system of underground stems that are very brittle. Even small bits of these branches are capable of growing into separate plants, either by the development of the buds already in existence or by the formation of adventitious buds. On account of this special feature these plants are the most troublesome and persistent weeds.

Adventitious buds develop at the margin of the leaves of *Bryophyllum calycinum* and these buds grow into separate plants. In *Scilla indica*, when the leaf apex comes in contact with the moist soil, an adventitious bud is developed on it and this establishes itself as an independent plant. A Begonia leaf is induced to form adventitious buds by making incisions in them, and these buds are used for propagation. Very often the callus formed at the cut ends of roots and shoots

develop adventitious buds. This affords another means of propagation.

There are many plants with subterranean stems in which the reserve food material is stored in abundance, such as rhizomes, corms and bulbs that are specially adapted for the propagation of their kind.

The aerial branches developed from stolons or rhizomes remain connected with the underground stem, until they become fully established. Afterwards they are capable of separate existence as individuals. Soon after separation they are able to carry on the work of nutrition because they possess roots and green leaves.

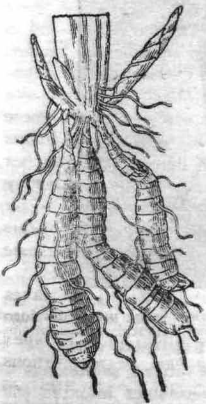


Fig. 233.—Rhizomes of Arrowroot.

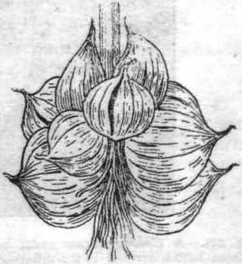


Fig. 234.—Onion bulbs.

Now coming to the very much modified stems such as thick rhizomes, tubers, corms and bulbs, these are

certainly much better fitted for vegetative propagation than stolons or runners, as the abundant storage of reserve food is a positive advantage to start their growth. In these cases the separation from the main plant may take place long before the appearance of the daughter plants.

Fig. 235.—A *Chlorophytum* plant bearing young plants developed from bulbils formed in the inflorescence. 1, rachis of the inflorescence; 2, young plants on the rachis; 3, roots of the plant.

In the potato plant tubers are formed at the ends of branches, after they burrow themselves into the soil. Sometimes even the seedling of a potato raised from a seed may form tubers from the axillary buds of the cotyledons. These tubers are capable of growing into separate plants when detached from the parent plant.

ome plants form small aerial tubers in the axils of erial branches. In many cultivated species of *Dioscorea* erial tubers develop from the axils and these fall off

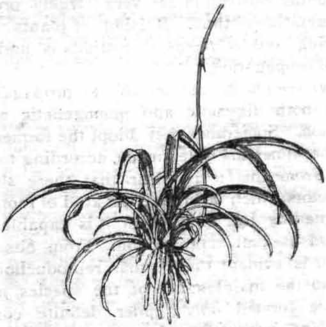


Fig. 236.—*Chlorophytum.* A bulbil of the inflorescence grown into a plant.

and grow into separate plants. In some species of *Agave* bulbils appear in the inflorescence and they drop down and develop into separate plants. We often find in some species of *Chlorophytum* grown in gardens bulbils in the inflorescences and they develop aerial roots and leaves in abundance before they get detached. (see figs. 235 and 236.)

In a corm the reserve material is allowed to accumulate in the main stem and all the buds remain on the surface of the corm. (see fig. 52.) All the buds found in a corm are capable of developing into new corms in their turn, although it is the terminal bud which usually grows and becomes the new corm. Generally

corms of two or three seasons remain together. In bulbs we find many daughter bulbs, which are really axillary buds, and by these the plant is multiplied.

Plants under cultivation are very largely propagated by the vegetative method. Raising of plants by grafting, layering and by means of cuttings is undoubtedly vegetative propagation.

Often we see plants that are able to propagate themselves by both digenetic and monogenetic modes of reproduction. Sometimes they adopt the former method and at other times the latter mode, according to circumstances. From this it is clear that there should be certain factors which determine the kind of reproduction to be adopted by the plant, when it is capable of both sexual and asexual reproduction. From observations in nature it is evident that sexual reproduction is not essential to the maintenance of the species and that flowers are formed only under definite conditions. When a plant gets plenty of water and nutrient salts ınd is able to carry on the work of photosynthesis, t continues to grow purely vegetatively. If the ıbsorption of water and salts is limited, even with good ight for photosynthesis, the plant produces flowers. 'lants with a moderate absorption of water and nutrient alts produce flowers when the illumination is strong, nd in weak light vegetative growth alone takes place.

Plants can propagate themselves continuously by egetaive reproduction. Cases are known especially nong cultivated flowering plants where propagation is fected continuously only by this method. For instance, e Pineapple and *Musa paradisiaca* which are seedless ıd the sugarcane, which produces seeds under certain nditions, are always propagated only vegetatively. ıe Jerusalem Artichoke (*Helianthus tuberosus*) has

been known to be propagated only from tubers for over a century or two.

The nature of the offspring of a plant will vary with the kind of reproduction. If the offspring has resulted from vegetative reproduction, they will maintain the characteristics of their parent plant. The vegetative method of propagation will, therefore, enable any one to propagate a variety or form without any change in its character, and make it occupy the land quickly. But it must be remembered that plants produced by vegetative propagation are less able to withstand changes in their environments than those derived from seeds. With plants produced by the sexual method, it is far otherwise. In this case the fusion of cells from two different individuals, which is the chief feature of the process changes the character of the offspring in a profound manner. Generally the offspring differ from their forbears in some respects at least. Some of the offspring may be like one parent, some like the others and some others may differ from both. No doubt the young plants may resemble the parents in a general way, but on close inspection differences also will become apparent. This tendency is an advantage, if new varieties are required, and in nature it leads to the formation of new plants. To make this point clear we may take the case of the propagation of the mango. If one wishes to have mango plants of a particular variety in large numbers, he should adopt the method of grafting, *i.e.*, vegetative propagation, but if the object is to obtain different varieties, he mus- have recourse to seeds that result from sexual reproduction.

Heredity :—The individuals of a species are fundamentally like their parents, and this holds good even if we take into consideration successive generations.

For example, a bean plant always produces a bean plant and no other when its seeds are sown. This is true of all plants. The characteristics of parents are repeated in their progeny. This repetition of the properties of the parents in their progeny from generation to generation is called **inheritance** or **heredity**.

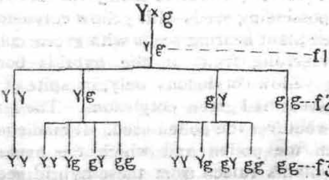
The beginning of every plant is always a piece of an antecedent plant, the parent and, therefore, the offspring naturally partake of the nature of their parents. This will become obvious if we consider the main features of reproduction in plants. The unicellular plant *Pleurococcus* divides into two daughter cells by cell division. Since the protoplasm of the single cell is equally distributed between the two daughter cells, the protoplasm of the parent cell and that of the daughter cells must be identical. So the daughter cells develop all the characteristics of a *Pleurococcus*. Even in higher plants, so far as vegetative reproduction is concerned, the new plant is obviously a portion of the parent plant, isolated and growing independently by itself. Here we have to assume that the germs giving rise to new individuals possess **determinants** or **genes** which determine that a plant shall react in a definite manner to the external conditions. These determinants appear to be in the chromosomes of the nucleus. So the separation of a part of the parent plant does not bring about changes in the protoplasm in any way and the inheritance also would not be affected. This is because all the cells contain the same determinants, the cells being formed by indirect cell division.

But in the case of the higher plants with sexual reproduction complicated changes occur in the formation of the male and the female gametes. Although the spore mother-cells are derived from the somatic cells of the

spring must be accurately determined. So it would be a distinct advantage if the parents differ in strongly contrasted characters. Then it would be easy to follow the behaviour of these characters in the hybrids and the generations raised from them. It must, however, be remembered that the facts of heredity deduced from the study of hybrids apply as well to inheritance from similar parents.

The laws of heredity can only be discovered by a consideration of the hybrids and their parents, since the individuals of a pure species have the same determinants. To understand the work of Mendel it is necessary to consider some illustrative examples. He crossed a pea plant possessing seeds with yellow cotyledons with another pea plant bearing seeds with green cotyledons, and the resulting fruits in the hybrids bore seeds containing yellow cotyledons only, in spite of the fact that one parent had green cotyledons. The result was the same whatever the pollen used. It made no difference which the pollen and which the ovule parent. When the plants raised from these hybrid seeds were self-fertilised, the resulting fruits bore seeds with yellow cotyledons and green cotyledons. The character yellow appeared in both the generations, whereas the green colour occurred only in the second. In other words, the green colour was latent in the first generation. The yellow was called the **dominant** character because it dominated in both the generations, and the green **recessive** on account of its being hidden in the first generation. Such characters as these that do not blend, but remain quite distinct and independent, are spoken of as **unit characters**. Alternative pairs of characters, such as the above, yellow and green that behave as dominant and recessive have been named **allelomorphs**.

In the hybrid plants, after self-fertilisation, seeds with yellow cotyledons and those with green cotyledons appeared in a definite ratio. There were three seeds with yellow cotyledons to every one seed with green cotyledons. By further selfing it was found that seeds with green cotyledons produced only seeds with green cotyledons. But out of the yellow only one bred true, and the remaining two did not breed true, when selfed. Instead of producing only yellow seeds they produced seeds with yellow and green cotyledons in the proportion namely, 3 to 1 or 1 : 2: 1. These results may be expressed in a tabular form as shown below :—



From the results stated above, it is obvious that, when hybrids are propagated by seeds, only one half of the progeny will show the hybrid character, the remaining half resembling the pure parents.

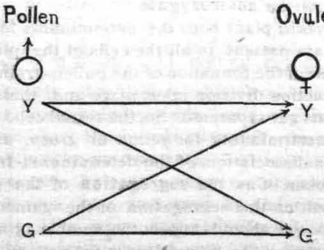
Sometimes the hybrids possess a character intermediate between those possessed by the two parents. For example, if a white flowered *Mirabilis jalapa* is crossed with a red-coloured one, the hybrid plants bear rose-coloured flowers only. When these are selfed, the individuals of the second generation produce plants bearing white, red and rose flowers in the proportion of 1 : 1: 2 respectively. Amongst the plants of the second generation the red and the white flowered

ılants breed true on selfing, whilst the plants with rose oloured flowers on selfing produce all the three coloured lowers in the ratio 1 white : 2 rose : 1 red.

To explain the behaviour of these contrasting characers Mendel formulated a theory. He conceived the idea hat the gametes could contain the determinants of only ne of the two contrasting characters, and not both of hem. So when fusion takes place between the male ;amete contained in the pollen-grain and the female ;amete contained in the ovule, both possessing the leterminants for yellow, the resulting fertilised egg-cell r the **zygote** must necessarily contain a double dose of he same *kind of genes or determinants. Such a zygote* is this is termed a **homozygote**. If, on the other hand, he pollen-grain contains determinants for yellow and he ovule for green, or *vice versa*, the zygote will contain leterminants for both the characters and this kind of ygote is called a **heterozygote**.

In the hybrid plant both the determinants for yellow ınd green are present in all the cells of the plant. But n the course of the formation of the pollen-grains and the ıvules, reduction division takes place and, therefore, the leterminants get separated. So, the sexual cells will have ither the determinants for yellow or green, and never ›oth. This dissociation of the determinants from each ›ther is spoken of as the **segregation of the gametes.** As the result of the segregation of the gametes in the exual cells, we should expect the number of reproducive cells bearing the determinants for yellow to be on he average equal to those carrying the determinants for ;reen. Therefore, when the hybrid plants are selfed, he union between the gametes of the pollen-grains and hose of the ovules could occur only in four ways. Out f the four gametes present in the plants there is just

one chance for the two sexual cells with determinant for yellow to unite and the resulting seeds will be pur for yellow; similarly there is one chance for the cell with the determinants for green which will also giv rise to a pure green seed; and there are two chances ou of four in which yellow will fuse with green. So ther will result one seed pure to yellow, one pure to gree and two with both yellow and green. This is exactl Mendel's ratio namely 1 : 2 : 1. Since the yellow colou is dominant and the green colour recessive, the hybrid will have only yellow seeds, though they contain th determinants for green. So the ratio of yellow seeds t green seeds would be 3 : 1. But in the case of *Mirabili jalapa* plants, above mentioned, the ratio would b 1 white : 2 rose : 1 red. These facts are graphically show in the following diagram :—



= YY+YG+GY+GG

i.e YY+2YG+GG

Although the theory of segregation and purity o gametes was a mere speculation at the time of Mendel we now know that such a separation of the chromo

omes occurs in the formation of spores or sexual cells. n all plants the somatic cells contain in their nuclei a ixed number of chromosomes according to the species. 'urther, all the somatic cells should necessarily contain :hromosomes that are identical in their character. But he pollen-grains and ovules (egg-cells) do not conain the same number of chromosomes as the somatic ells, as they are formed as the result of reduction livision in the first instance, although the subsequent livision is ordinary cell division. These usually contain nly half as many chromosomes as there are in the omatic cells. In consequence of this difference in the node of cell division, the sexual cells must necessarily ave chromosomes having different sets of determinants, nd they cannot possibly be all identical. The nature of the zygote, in this respect, will depend upon the naure of the gametes that have fused to form the zygote. Since the zygote divides and developes into the adult plant, the adult plant has in every cell of its body chronosomes, or hereditary material, derived from both of ts parents.

The reduction division leading to the formation of the ex cells with only half the number of chromosomes has most important physiological significance. Supposing he sex cells that fuse to form the zygote contained the ull number of chromosomes, then the zygote will have louble the number of chromosomes and in the next generation a further doubling must occur, and if this goes on there will result a piling up of the chromosomes. The object of reduction division is thus seen to be to prevent the enormous multiplication of chromosomes nd to keep the number constant.

In the illustrative examples, so far considered, we paid attention only to a pair of contrasting characters

for the sake of clearness. Such hybrids are called **monohybrids.** But every plant is an aggregate of unit characters and so in the crossing of plants several pairs of such characters may be involved. Whatever may be the number of pairs of such characters, the behaviour of each pair conforms to the laws of Mendel already described. We may next consider the case of **dihybrids**. Mendel crossed plants having peas possessing yellow cotyledons and round in shape with pea plants bearing wrinkled seeds with green cotyledons. The hybrid plants produced only round yellow peas. The characters, wrinkledness and green colour, did not appear in any of the seeds of the hybrids. On self-fertilising the individuals of the first generation four distinct types of seeds appeared in the fruits formed on the plants. They were (1) round seeds with yellow cotyledons, (2) round seeds with green cotyledons, (3) wrinkled seeds with yellow cotyledons, and (4) wrinkled seeds with green cotyledons. The first and the fourth are similar to the parents, but the second and the third are new combinations. It is obvious that yellow and green form a pair of contrasting characters,and wrinkled and round another allelomorph, the characters yellow and round being dominant. As these are only two pairs of characters, the possible combinations are only four. It must also be remembered that each of these allelomorphs behaves independently of each other. When the proportion to one another of the seeds produced by the hybrid plants after self-fertilisation was considered it was found to be as follows :—

9. round yellow ; 3. round green ; 3. wrinked yellow : 1. wrinkled green. Of these, the single wrinkled green seed bred true on self-fertilisation. Out of the nine yellow only one was found to breed true. The remaining

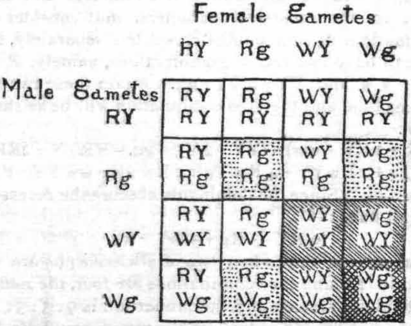
urteen were always found to split, and did not come
ıe to the breed. To make out all the details clearly
; should consider all possible combinations. If we
present the two pairs of allelomorphs by letters using
pital letters for the dominant characters and small
tters for the recessive characters, and consider the
ımbinations of each pair of characters separately, then
e shall have two sets of combinations, namely, R R +
Rw + w w and YY + 2 Yg + gg. Again these two sets
ay combine and then the combination will be as shown
:low :—
(RR + 2 Rw + ww) × (YY + 2 Yg + gg, = RRYY + 2RRYg
RRgg + 2 RwYY + 4 Rw Yg + 2 Rw gg + ww YY + 2 w w
g + ww gg. Since the dominants obscure the recessives
e shall have :—

9 RY + 3 Rg + 3 wY + wg.

Thus we see that when two of allelomorphs are con-
:rned in crossing the combinations are four, the number
individuals sixteen and the proportion is 9 : 3 : 3 : 1.
In the hybrid individuals the gametes would be RY,
g, wY and wg both male and female and the possible
ımbinations are indicated in the diagram on page 350.
The nine combinations that are in the white squares
ould be alike in external appearance and all of them
ould have round seeds with yellow cotyledons. This
because both the dominant characters R and Y occur
ı the combination. Out of these nine, only one having
ıe combination RR YY has pure dominants i.e., homozy-
ous and this will breed true. In the remaining eight,
vo are homozygous for R only, two for Y only and four
eterozygous for both pairs of characters.
The three, Rg Rg, Rg wg, and wg Rg found in the
ıuares with dots would have round seeds with
reen cotyledons, R being dominant over w. The

character Y is absent. One is homozygous for both R and g, two homozygous for g only.

The three, wYwY, wYwg, and wgwY found in squares with oblique lines would be wrinkled seeds with yellow



cotyledons, Y being dominant over g. The character R is absent. One is homozygous for w and y and two homozygous for w only.

One wgwg in the square hatched with crossed lines is a wrinkled green seed. Both R and Y are absent. This is homozygous for both w and g.

Mendel's experiments were practically confined to the pea plants and consequently, he met with only simple conditions of inheritance. Recent investigators have not only verified repeatedly Mendel's laws in many plants, but also have observed many new situations not known to him. In fact, there has been a great extension of our knowledge in the field of heredity, as this knowledge has considerable bearing on breeding work.

Every investigator observes the character of the plant ıd tries to find out which of them do mendelize, as a ·eliminary step for further work. For example, Biffen ound in wheat plants that beardless ear was dominant bearded ear, red grain to white grain and felted umes to glabrous glumes. In the paddy plant Parnell ıs noticed several allelomorphic pairs. When ordinary ıddy with short outer glumes was crossed with a ıriety of paddy with long outer glumes, the short glumes ere dominant to long outer glumes. Other contrasting ıirs of characters that were found are these :—blackish-rown glumes of Pisini variety dominant to golden lumes of Ponkambisamba ; purple pigmentation in the ps of glumes or the axils of leaf sheaths to absence f pigmentation ; purple internode dominant to green ıternode.

According to the views of Mendel both dominance and cessiveness are due to two distinct factors. It is not ossible to explain satisfactorily all the cases that have een observed recently. Now the dominance of a cha-ıcter over another is not a question of two contrasted eterminants, as was held by Mendel, but a question of ıe presence or absence of a determinant or factor.

The main conclusions and discoveries of Mendel may e briefly stated as follows :—

(1) He viewed a plant as an aggregate of characters nd found that characters do not blend and that each haracter behaved as a unit and separates completely rom one another.

(2) In the case of two contrasting characters one was ound to be dominant and the other recessive.

(3) The gametes or the sexual cells are always pure nd they contain the gene or determinant for only one f a pair of allelomorphs, and even if the genes for both

the characters enter the zygote, very soon segregation takes place in the sexual cells of the first generation when they form their pollen-grains and ovules.

(4) The offspring of a hybrid consist of dominants and recessives in the ratio of 3 : 1; the recessives and one-third of the dominants breed true, while two-thirds of the dominants breed as hybrids producing dominants and recessives again in the ratio of 3 : 1.

(5) Even when a number of allelomorphs are concerned each pair behaves independently, and further all combinations of characters according to the mathematical laws of combination can be obtained.

The value of the discoveries of Mendel is very great. All the truths established by him are of enormous importance to breeders. His laws enable the breeders to know what the effects of crossing would be and to interpret results which were not understandable. Owing to the discovery of the segregation of the gametes we now know that, in the second generation of hybrids, individuals that are perfectly pure occur in definite proportions, and that purity of plants in respect to a character does not depend upon a long series of selection as was formerly the notion. Characters found in different plants may be combined in one plant, taking advantage of the fact that contrasting characters behave independently. New types of plants may be produced by the recombination of pre-existing characters. If the characters that are to be recombined are recessive, one can very easily get the combination by crossing twice, and the plant having the combinations would breed true on self-fertilizing. But when the characters to be recombined constitute a mixture of dominants and recessives, the work is not so easy. Several crossings and selections would be necessary.

Origin of species :—The vegetation on the surface of the earth consists of different kinds of plants, some simple and others highly organised. It is but natural for any one to ask how the plants with their morphological peculiarities have arisen. Once it was assumed that all plants were independently created. This assumption would mean that flowering plants, ferns, mosses and other groups of plants, however simple or complex have been in existence practically ever since the world began without much change. This conception of the fixity of the species could not, however, be supported by facts.

From a study of the various groups and species of plants, we have to conclude that the different kinds of plants now in existence are developed from simpler forms of plants which lived in the earlier periods of the earth's history. This fundamental idea that plants and animals living at the present time are the lineal descendants of ancestors which are simpler, and that these were descended from yet simpler ones that lived in still older times is **Organic Evolution** or **Theory of Descent.**

This Theory of Descent involves the assumption that organisms are subject to a continuous process of change which is operating from the beginning without cessation and which is still in progress. In other words, we have to understand that living beings were not in the beginning as we now find them, but that there have been constant changes in them. A general review of the Flora and Fauna of the present and past ages shows that in the early history of the world there were only simple plants and animals, and that the complex forms came into existence only later. Since organisms are subject to the laws of inheritance, new species of plants or animals can be derived, from species already in

existence by inherited changes. If these changes ar more striking, then they give rise to genera and familie

The highly organised plants must have been derive from very simple plants such as *Pleurococcus* throug heritable changes involving many thousands of year The developmental history of an individual **(ontogeny** from a spore, or that of a group of related form **(phylogeny)** *tell the same story. One of the aims of th* Science of Botany is to record, as far as it is possibl and in order, the evolutionary steps that have culminate in the present condition of the plant.

The Theory of Descent was a mere speculation unt the publication of Darwin's great book "Origin o Species" in 1859. He has given overwhelming evidenc based upon experiment and observation in support o this theory. He holds that species of plants and ani mals came into existence by the process of evolution an that evolution rests on **Natural Selection.** The influ ence of Darwin is now seen in all branches of knowledg and the theory is accepted by all scientists.

As regards the methods of evolution several hypo theses were advanced from time to time, and Lamarc held that living beings were changed by their environ ment and also by the use and disuse of organs, and the the changes induced in the organisms were inherited b their progeny and were accentuated from generation t *generation. But, although changes are produced i* organisms by their environment, these are not inherite by the offspring.

Charles Darwin pointed out that a perpetual struggl is going on amongst plants and animals and that as th result of this struggle only those best adapted to th surroundings survive. Since the individuals that surviv are only few and those that perish numerous, he consi

dered this survival of a few as a kind of selection in nature and hence named it **Natural Selection**.

This theory of Natural Selection or Darwinism, as it is sometimes termed, is based upon the conceptions, namely, increase in progeny, struggle for existence, variation, survival of the fittest and heredity.

Increase in progeny :—We already know that plants usually are prolific in the matter of the production of seeds or spores. If all the seeds produced by a plant in successive generations were to germinate and develop into adult plants, there would scarcely be room for other plants. For example, we may consider the case of a single plant, such as the weed *Argemone mexicana*. A single plant of this species produces from twenty to thirty thousand seeds in a season. Taking the average of the production of seeds at twenty five thousand, the progeny of one plant would be 15,625,000,000,000 in the third generation, if all the seeds germinate and grow into plants. Supposing each of these plants occupy a square foot of the soil, then the plants of the third generation will cover nearly five hundred thousand square miles. In spite of this prolificity in seed production, we do not find any abnormal increase in these plants in any season, even if the observation is continued through several seasons. About the same number of plants appear year after year. This approximate uniformity in the number of plants of a species, year after year, is due to severe competition amongst them at every stage. All the seeds of a plant do not obtain the conditions necessary for successful germination. In the seedling stage again there would be a struggle amongst them for water, salts and light. Only those seedlings that are capable of vigorous growth would be able to survive in the competition. Such seedlings would be able to get more

water and light than the others with slow growth. Ir the end the weaker ones with slow growth must perish This quality of vigorous growth in the seedling stage is a variation that enables certain plants to survive. But for this variation there would be no selection and survival of the fittest ones. Thus we see that Variation is the most fundamental fact in the theory of Natura Selection.

Variation :—The individuals of any species of plant resemble one another in certain respects only, but they are not all alike. If we compare the individuals closely with reference to any one character, we find that no two individuals are exactly alike, and that each has its own individuality. This fact is termed **variability**. For example, if we look at the leaves of the weed *Lactuca runcinata*, we find them varying very much even on the same plant. (See fig. 237.)

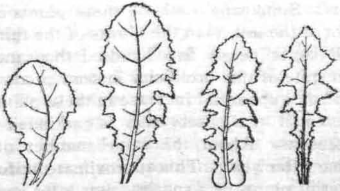


Fig. 237.—Leaves of *Lactuca runcinata* from the same plant.

In plants, even if they are pure in origin without any admixture, we notice variations. If we consider the causes which bring about the variations, we have three kinds of variations, namely, **modifications** or **continuous variations, mutations** or **discontinuous variations**

nd **combination**. The *modifications manifested* by lants are chiefly due to differences in the environment, uch as differences in sunlight, food and water-supply, nd influences exerted by one organism on another. Such ariations as these are not inherited and they persist only s long as the environmental conditions exist. In pracice even individuals that are homozygous belonging to pure line exhibit quantitative differences, although they re grown under similar conditions. Modifications or ontinuous variations fluctuate around a mean or average. 'hey are quantitative, and the average remains practially constant. The individuals having variations above r below this average become less and less in number, s the variability departs more and more from the aveage, until a limit is reached in each direction. The umber of individuals having a variation which diverges rom the mean to a small extent is generally large, and ndividuals with larger divergences are less in number. f we, for example, examine the seeds of the bean plant n a measure of seeds, no two seeds would be precisely of he same dimensions. In this connexion an actual experiient conducted by Hugo De Vries may be quoted. He hose at random 450 beans from a quantity purchased in he market and measured them all. The variation in ength was from 8 to 16 millimeters and the number of eeds of definite measurements were as given below:—

Millimeter 8,—9,—10,— 11,— 12,—
Number of beans 1,—2,—23,—108,—167,—
Millimeter 13,—14,—15,—16
Number. 106,—33,— 7,— 1

He then sorted them in nine compartments according their lengths. The tops of the columns when joined orm a curve of chance called Quetelet's curve. (See g.238.)

From the curve we see that the greatest frequency coincides more or less with the mean dimensions and that the more the divergence from the average the less frequent is its occurrence.

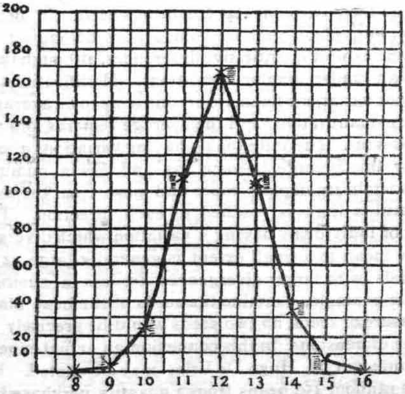


Fig. 238.—Quetelet's curve. The numbers horizontally placed refer to millimeters and the vertically placed denote the number of seeds.

As modifications fluctuate around an average from generation *to generation in plants, it is not possible to* cause any improvement in any variation even by very careful selection. It is not, therefore, possible to obtain any improvement of a permanent character in these continuous variations.

The variation called mutation or discontinuous variation was discovered by Hugo De Vries. These variations are inherited by individuals from their parents. It is only

by experimental work that it is possible to find out the mutations. They appear suddenly and the cause is not yet fully understood. A change in the determinants is believed to have occured in the mutation. Hugo De Vries holds the view that species are formed by the selection of mutations and not by the selection of modifications.

Survival of the fittest:—It is obvious that the individuals that survive without perishing in the struggle for existence, must be those best suited for the environment. And the survival is due to their having some variation enabling them to adjust themselves to the environment. Those not possessing this variation cannot adjust themselves and consequently they must ultimately perish.

Inheritance or **heredity** :—Unless the variations appearing in plants are inherited by their progeny, it is impossible to have new species of plants. Those that survive the struggle transmit the useful variations to their offspring, and if this goes on from generation to generation, the variations increase and we get new species of plants.

Darwin and Alfred Russel Wallace held the view that specific distinctions come into existence by natural selection acting upon individual differences. According to this view all kinds of variations though slight are inheritable and they can become intensified through generations of selection and finally become distinct characters of new species. Another theory, the theory of mutation, is offered as an explanation of the origin of species. According to this theory mutations are inheritable and they are not built up through generations of selection, but they arise suddenly, in full force, and breed true. New species arise at one bound, according

to this view, and all that natural selection has to do is to determine whether they shall survive or perish. If the mutation is one which would enable the species to adapt itself to the environment, the plants survive, if not, they perish.

There are two more theories of evolution deserving mention. Some hold that each species of plant or animal sometimes shows progressive changes in a definite direction and that these are not dependent on changes in their environment. The external factors have no influence. It is presumed that the cause is within the organism itself. The evolution of great groups is accounted for by this theory.

Plants growing in isolation being separated from the general mass of plants is also believed to develop into species. So isolation also is put forth as a factor in evolution.

SECTION III
CRYPTOGAMS

CHAPTER XVIII

THALLOPHYTA—THE ALGAE

[E lowest and simplest of plants are collectively signated Thallophyta. They are either unicellular or ılticellular. The multicellular forms may consist of ls forming a cell-row or filament, a cell-surface or ıple tissue layer, or lastly a colony or mass of cells :reasing in size in every direction. Under Thallophyta : included the Algae and the Fungi. As regards their ıde of life, the Algae are autotrophic, since they are pable of carrying on photosynthesis, in virtue of their ssessing chlorophyll in their protoplasts, while Fungi ve to live either as saprophytes or parasites, because ey do not possess chlorophyll.

The thallus or plant body of Thallophytes shows a nsiderable amount of variation. We have forms of the most conceivable simplicity side by side with massive ants. The simplest forms consist of single cells, ıilst the massive ones consist of complex forms of cells nstituting a tissue. But in spite of this complexity, e *tissues are homogeneous, and the sharply marked* ssue-systems so characteristic of the higher plants do t *occur.*

These two groups, the Algae and the Fungi, really nsist of *distinct smaller groups or phyla.* If we conder in detail the forms belonging to the different oups, we find that in each group the plants may be so ranged as to show progressive development from mple to complex forms. Many would be found to be r advanced in evolution.

Notwithstanding the simplicity in the organisation of some plants, we find in certain phyla a great variation in the process of development. In simple forms such as the *Protococcus* the thallus consists of a single cell with a smooth thin cell wall enclosing the cytoplasm, the nucleus, the chloroplast and the cell sap, which are only imperfectly distinguishable. In some plants complexity is attained by the increase in the number of cells and by changes in their form. We have also a few forms of plant life, such as *Botrydium, Vaucheria, Valonia, Acetabularia* and *Caulerpa* in which we find the single cell attaining extraordinary development in size and in the cell-contents, which is without any parallel in the vegetable kingdom. Such plants are considered to be coenocytic.

Even in the matter of reproduction there is much variation amongst the Thallophytes. Some of them multiply only asexually, while others do so both by asexual and sexual reproduction. The simplest mode of asexual reproduction is the breaking into pieces, and each piece growing and continuing to live independently. In some plants separate cells of the thallus persist after the decay of others and become resting-cells. These cells or **resting-spores** are able to withstand very well the effects of dessication. Fungi and many Algae produce spores in abundance. It must be remembered that spores are single cells, and the organ of reproduction which separates from the mother-plant is always a single cell.

Sexual reproduction also occurs widely amongst the Thallophytes. In the simplest cases motile gametes or sexual cells are formed. These unite and form a zygote. The gametes are alike in form in some plants and then they are termed **isogamous**, while in others a smaller

mete, the male one fuses with a larger one, the female mete and these are, therefore, called **heterogamous**.

THE ALGAE

The Algae are adapted for aquatic life, and so they e mostly in water or in damp situations. Many of em live in fresh water, but a great majority live in the a, constituting the assemblage of plants known as aweeds. All the green pond scums and green filaents found in fresh water are Algae. They are most verse in size, form and habit. Whatever their form ıd size, all of them possess well differentiated cells. mongst the fresh water forms of Algae we can disıguish two distinct kinds, namely, the Blue-green lgae or Cyanophyceae and the Green Algae or Chlorohyceae.

CYANOPHYCEAE

The Blue-green Algae occur everywhere in wet situtions, and they are the most primitive amongst the ılgae. They are very simple forms of plants containing blue-green pigment instead of a pure green one. The hallus is either unicellular or multicellular. All plants f this class secrete mucilage copiously and, therefore, hey are invested with mucilaginous sheaths, or imbedled in a jelly-like mass of mucilage.

The cells contain protoplasm, but without any nucleus. By careful fixing and staining of these plants, it is possible to make out certain diffuse granular bodies of the nature of chromosomes in the centre of protoplasm in every cell. This may be considered an incipient nucleus. The blue-green colouration is not very deep under higher magnifications, but very light in colour. The granulation of the protoplasm is not easily visible.

Many of the Cyanophyceae are unicellular, and as examples we may mention the genera *Gloeocapsa*, *Gloeothece* and *Merismopedia*. All these genera, though unicellular, are usually found held together in mucilaginous sheaths, the number of cells being two, four or more. After cell division the daughter-cells do not completely separate from one another, but remain embedded in the mucilage forming a colony.

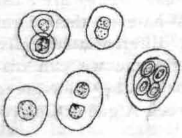


Fig. 239.—*Gloeocapsa*.

For the filamentous type we may consider the genera *Oscillatoria* and *Nostoc*.

Oscillatoria Vaucher:—Most of the species of *Oscillatoria* grow as dense slimy tufts attached to floating bodies or stones. The patches of bluish green or dark slimy stuff found growing on walls, stones or the surface of the ground, when wet, consist mostly of species of this genus. They consist of rigid cylindrical filaments, varying in thickness from .006 to .05 of a millimeter according to the species. The filaments are divided into uniform short disc-shaped cells. Usually a very delicate thin sheath of mucilage exists though not distinct. This is why the filaments are slimy to the touch.

The filaments are capable of spontaneous movements. Each filament moves forward, and sometimes backwards also, at the same time rotating on its own axis. If we watch the movements of a filament under the high power of the microscope, we find that it takes about two minutes to cross the field of the microscope. The genus gets its name from this peculiar oscillating movements exhibited by the filaments.

Propagation is effected only vegetatively. From the extremeties of the main filaments short pieces become detached and these move about in a spiral manner and ultimately develop into long filaments. These short pieces are termed **hormogones**. This is the usual method of multiplication. But occasionally a single cell in a filament becomes changed into a resting-spore, which germinates and grows into a filament.

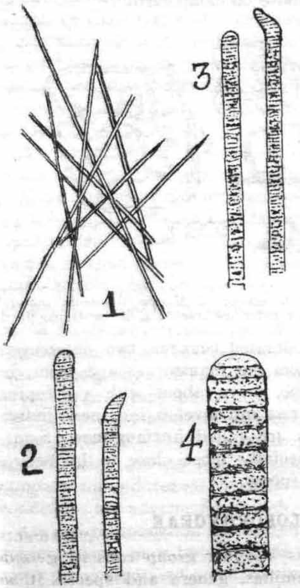


Fig. 240.—Two species of *Oscillatoria*. 1, Slightly magnified; 2, highly magnified; 3, slightly magnified; 4, highly magnified.

Nostoc Vaucher:—The filaments of *Nostoc* are simple consisting of a single series of uniform and often moniliform cells, which are interrupted here and there by clear slightly larger cells containing only water, called **heterocysts**. Generally these filaments occur in large numbers crowded together in jelly-like

masses, often of considerable size and definite outline These lumps of mucilage or gelatinous envelopes eithe float on water or lie loose on damp earth.

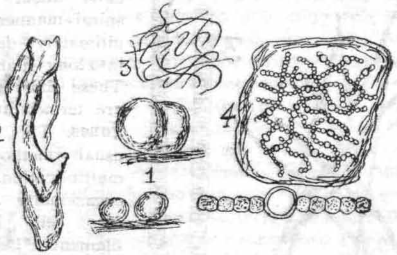


Fig. 241.—*Nostoc.* 1 and 2, masses of *Nostoc* filaments (natura size); 3, filaments as seen under low power; 4, filaments magnifiec

Pieces of filaments situated between two heterocyst detach themselves from the filament escape from th mucilaginous envelope, move about with a creeping motion, then come to rest and develop into new indivi duals. These pieces are called **hormogones.** Some times single cells, especially those close to the hetero cysts become resting-spores.

CHLOROPHYCEAE

The Green Algae is a wider group consisting of a larger number of families, genera and species thar Cyanophyceae. The chloroplasts are bright, green, larg and variously shaped. They are usually peripheral ir position in the protoplast. These plants attain thei greatest development in fresh water, and they are mos diverse in their cytological structure and life-history.

There are many Green Algae that are unicellular and hese are the primitive forms of the group. In some plants the whole of the thallus consists of the so-called single cell, but really an aggregate of protoplasts with a common cell wall. Such plants, as already stated, are lescribed as coenocytic. Amongst the multicellular orms, we find the thallus developing into simple or branched filaments, colonies, flat expansions or into masses of tissue.

All the cells are provided with chloroplasts, and a nucleus is found in every protoplast.

Naturally in unicellular Algae multiplication is effected by cell division, and in the filamentous forms this occurs by fragmentation of the filaments. Although propagaion is effected in most of the lower Algae by vegetative eproduction by cell division or fragmentation, the higher forms multiply themselves by means of spores ormed asexually or sexually. The occurrence of sexual eproduction or asexual reproduction seems to be depenlent largely on external conditions. Both spores and exual organs may be formed on the same plant, but hey are usually found at different times and not at the ame time. It may be stated generally that when onditions of growth are favourable asexual reprodution occurs and sexual reproduction takes place, when onditions are adverse for growth.

Asexual reproduction is effected by the formation of pores, which may be motile or non-motile. In some ases the contents of a cell become transformed into a esting-spore. But often the protoplasm of a single cell hanges by rejuvenescence into a single motile spore. n some Algae instead of one spore many are formed in cell. These motile bodies are called **zoogonidia** or **oospores.**

In the matter of sexual reproduction in the Green Algae we have interesting and unique forms. In the first place, we have sexual cells which are externally alike and such ones are called **isogametes.** We have in some Algae gametes or sexual cells that are unlike, one being larger than the other. The larger sexual cell is called the female gamete and the smaller the male gamete. On account of this difference in size these are termed **heterogametes.** The union of the gametes results in a **zygote,** and it is called a **zygospore** when the gametes are isogamous and **oospore** or **oosperm** when they are heterogamous. The zygote may develop directly into the plant, or it may become divided into zoospores. each of which then growing into an individual plant.

As typical examples of Green Algae we shall select *Chlamydomonas, Protococcus. Ulothrix, Spirogyra, Oedogonium* and *Botrydium.*

Chlamydomonas Ehren :—The organisms belonging to this genus occur very largely in pools and puddles of rain water. The plant consists of a single ovoid or oblong cell provided with two cilia. It moves about freely for sometime and then it may rest and move about again. The protoplasm contains a nucleus and a chloroplast is imbedded in it posteriorly. Usually the chloroplast is cup-shaped in several species and has a pyrenoid body in it. The portion bearing the two cilia is the anterior part of the organism and it is somewhat pale and colourless. Just close to the cilia may be seen two vacuoles. A red pigment is also found at the anterior end.

Often organisms of the species of *Chlamydomonas* enter into the resting stage called "palmella-state." In this condition the individual plant comes to rest,

loses its cilia and pigment spot, and the cell wall swells and becomes *mucilaginous.* *Within this mucilaginous* envelope the cell begins to divide very actively and the cells remain aggregated together. As division takes place in all directions the colony may extend in all the three dimensions.

Chlamydomonas is a very important and interesting genus amongst green plants. All chlorophyll-bearing plants are believed to be derived from this organism. The "palmella-state" of *Chlamydomonas* is very significant and striking. By the extension of this quiescent stage and the loss of the motile state, it may have given rise to the Palmellaceae. Thus it has to be regarded as the phylogenetic starting point of green plants. The cells of the colony in the palmelliod stage of *Chlamydomonas* escape and become motile, on the occurrence of favourable conditions.

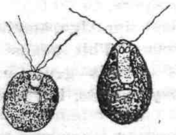


Fig. 242.—*Carteria* and *Chlamydomonas*. Highly magnified.

This plant varies in its mode *of reproduction, according to the* species. It is asexual or sexual according to the nutritive conditions. When the supply of food material is abundant asexual reproduction is the rule. In other words, *Chlamydomonas* can be induced to enter the palmella-state by growing it in nutritive solutions. Under conditions of starvation sexual reproduction occurs.

When these organisms are allowed to grow in Knop's or Crone's solution the contents of the cell become divided into four ovoid cells by cell division. These four inner cells sooner or later begin to move within the large cell and finally escape as zoogonidia, which develop into *Chlamydomonas* plants. Very rarely

even eight zoogonidia are formed instead of four. This is the usual method of asexual reproduction.

In some species the contents of the cell break up into thirty-two or sixty-four small biciliate motile spores or **zoogametes**, all alike in size and shape. These motile bodies fuse in pairs and the resulting zygote acquires a thick coat and rests for a time. As a general rule, the gametes that unite together come from different individuals. The zygospore germinates and the protoplasm gives rise to four or eight cells, and each of these develop cell walls and cilia and then become independent individuals.

Besides this isogamous fusion, in some species, heterogamous union also is known to occur. The gametes that are formed are of two sizes, some smaller and others larger. Fusion takes place between the larger and the smaller ones and the resulting product is an oospore, which behaves exactly like the zygospore.

Very often mixed up with this unicellular Alga, another genus of Alga, also unicellur, occurs. This genus is called *Carteria*. The individuals of this genus are exactly similar to those of *Chlamydomonas*, but have four cilia in each plant.

Protococcus Ag :—This Alga occurs as incrustations on walls, bricks, and on the windward side of tree trunks. In wet weather the patches appear bright green and in dry weather they are dark green and are powdery. If a little of this crust is scraped and mounted on a slide in a drop of water, and examined with the high power of a microscope numerous small cells will be seen. Some of these cells, which are usually very small being about one two-thousandth of an inch in diameter, are separate and single, but they also occur in groups of two, four or more.

These cells are more or less rounded and have fairly thick and strong cell walls, which enable them to withstand considerable dryness. The single cell is really an individual plant, leading an independent life. Within the protoplasm is embedded a chloroplast, which in some cells is very much lobed. A nucleus is present, but it can be made out only with special treatment.

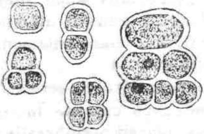


Fig. 243.—*Protococcus viridis* Ag. (*Pleurococcus vulgaris* Menegh). Highly magnified.

These individuals belong to the species *Protococcus viridis* (*Pleurococcus vulgaris.*) Since the cells of this species contain chloroplasts they can carry on the work of photosynthesis, and as a matter of fact, all the life processes essential for the well-being and growth of a plant are carried on by these cells. The amount of water and salts needed being so small, these plants manage to get them in their habitat, though it is not very suitable

Propagation is effected only by ordinary cell division. Each individual, as soon as it attains its adult size, begins to divide and form two cells. If these two daughter-cells separate, each of them grows into an individual attaining the average size and shape. But very often, the daughter-cells formed by cell division remain together, instead of separating, thus forming colonies of two, four or more cells.

This species is a cosmopolitan one with very wide distribution. Considering its habitat it is evidently exposed to extremes of temperature. During wet weather these plants grow and multiply very rapidly, as plenty of water is available. Under dry conditions growth is hindered and the plants remain in a resting condition

This Alga is more common in temperate climates than in tropical regions.

Ulothrix Kutzing:—This is a common filamentous form occurring by itself or mixed with other Algae. The filament is simple, without any branching, and it is usually attached to stones, leaves, and stems of other plants, or to filaments of other Algae. The filaments secure attachment at their base, especially when they are young, by means of rhizoid-like organs of attachment or **haptera**. The basal cell of a young filament becomes the **hapteron** or an **holdfast**.

The thallus or the simple filament consists of a series of short somewhat square cells, and each cell has in its protoplasm a plate-like chloroplast placed peripherally.

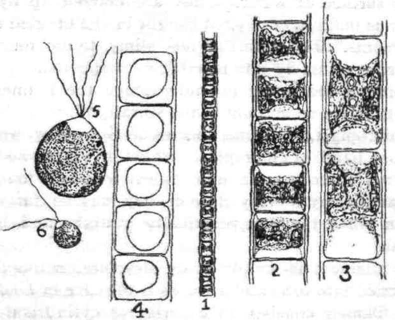
Propagation is effected by fragmentation of the filament into pieces and also by asexual or sexual method of reproduction.

The *Ulothrix* filament often gets broken into pieces by the decay of some of the cells and each of these broken bits is capable of growing into an individual.

The contents of a cell escape as a single zoogonidium or motile spore, or it may break up into two or more such bodies. Each of these pear-shaped zoogonidia is provided with four cilia at the anterior end. These motile spores escape through a lateral opening in the cell formed by the absorption of the cell wall. After moving about for sometime these come to rest, germinate and develop into filaments. This is the usual asexual reproduction occurring in *Ulothrix*.

Sexual reproduction is effected by the formation of gametes, all alike in size and shape externally. The protoplasm of a cell gives rise to a number of biciliated gametes, which are ordinarily incapable of developing into *Ulothrix* plants by themselves. They

ɪse in pairs and form zygotes, which in their turn, after ɪme period of rest, develop motile spores capable of :owing into *Ulothrix* filaments. The gametes that ɔalesce to form the zygote, as a rule, come from diffe-



ᶠig. 244.—*Ulothrix.* 1, A filament of *Ulothrix* slightly magnified; 2 and 3, bits of filaments highly magnified to show the cells; 4, a bit of the filament highly magnified showing zoospores; 5, a zoospore; 6, a gamete.

rent filaments, and fusion between gametes from the same filament does not occur. Sometimes, but only rarely, the biciliated motile spore may develop into a filament without fusing with another gamete.

Thus we see that *Ulothrix* is ordinarily isogamous in its sexual reproduction in many of its species, and it is interesting that the sexual differentiation of the sexual cells is incomplete in many species, in spite of the existence of two kinds of gametes. Some species how-

ever, are said to have two kinds of gametes or motile spores, one slightly larger than the other.

Spirogyra Link:—This genus is best known, and it is commonly found in ponds, ditches, streams and rivers, forming unattached masses of tangled green filaments on the surface of water. They are buoyed up by the numerous bubbles of oxygen caught in the tangled mass of filaments. The filaments feel slimy to the touch as they are invested by thin mucilaginous sheaths.

When viewed under the microscope the filament is very attractive on account of the spirally disposed band-like chloroplast. In some species of *Spirogyra* we find only one band of chloroplast, whilst in others we may have two, three or more upto twelve or even fourteen. The spirals may be very close or they may be far apart, and in some they are practically straight and longitudinal.

The filament is simple in its structure, without any distinction into base and apex, as is the case in *Ulothrix*. Each filament consists of a series of cylindrical cells which are longer than broad. All the cells have the same structure and each cell is practically an individual capable of a separate existence.

The cell wall is fairly thick and the transverse partitions between the cells are straight. A thin layer of protoplasm forms a lining to the cell wall in each cell and encloses a large central vacuole. In the median portion of the cell is suspended a nucleus which is embedded in a small amount of cytoplasm. From this cytoplasm numerous protoplasmic strands radiate and join the peripheral protoplasmic layer. On close inspection it would be seen that each of these strands join the protoplasmic layer just opposite the pyrenoid body found in the band of chlorophyll. The

shape of the nucleus is *ellipsoidal* in some species, and it is globular in others. The spirally disposed band-like chloroplasts are peripheral in position. In these bands

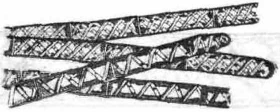


Fig. 215—.Filaments of different species of *Spirogyra.* Slightly magnified.

of chloroplasts small refractive bodies, the **pyrenoids,** occur at intervals. Starch grains are usually found aggregated around these bodies.

Propagation may take place by the vegetative method of reproduction. The filaments of *Spirogyra*, like other filamentous Algae, may break into fragments, each fragment consisting of one or more cells. Each separate bit is capable of cell division and growth into a long filament. Very often by this method *Spirogyra* spreads widely.

In addition to vegetative propagation, it reproduces itself by a kind of sexual reproductive process called **conjugation**. If old discoloured filaments are examined, there will be found some filaments in pairs, the two being connected together by tubes passing from a cell of one filament to another cell opposite to it in the other. In the cells of one of the filaments oval bodies will be seen, and none in the other. Each of these bodies is a zygote capable of germinating and developing into a *Spirogyra* filament.

The process of conjugation occurs in *Spirogyra* as described below. Two filaments of this plant come close together and lie parallel to one another. Small

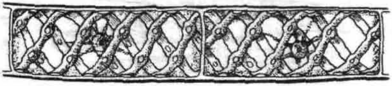


Fig. 246.—*Spirogyra* filament showing the nucleus, and the chloroplasts in their cells. Highly magnified.

processes arise simultaneously in the cells of the filaments that are opposite to one another. These two processes meet and, after fusion, a free passage is formed between the two cells. Then the protoplasm in one of the cells shrinks away from the cell wall and moves towards the connecting tube. The protoplasm in the opposite cell also gets separated from the cell wall and becomes somewhat rounded. The mass which passes into the passage finally enters the opposite cell and the two masses of protoplasm fuse and form the zygote. During fusion the chloroplast of the cell which passes through the connecting tube degenerates. While still young the nucleus of the zygote seems to undergo division into four cells and only one of these persists. During this process reduction in the number of the chromosomes is said to take place.

Although the gametes are non-motile and simple in *Spirogyra*, just the beginning of differentiation into sexes is apparent. The filament containing the zygote may be considered to be the female and the

other from which the protoplast moves through the passage the male filament.

The genus *Spirogyra* belongs to an extremely well-defined group Conjugatae. This is one of the most

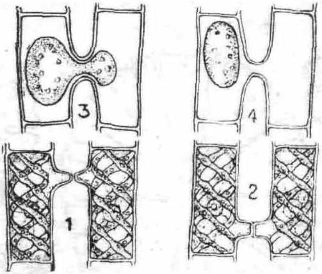


Fig. 247. Conjugation in *Spirogyra* and zygotes in the female filament. 1 and 2, filaments with the fusion-tube just meeting; 3, filaments with the zygote just forming; 4, filaments with the zygote fully formed. Highly magnified.

natural groups of the Green Algae. Besides *Spirogyra* and other filamentous forms, unicellular Algae called Desmids, are also included in this group.

The Desmids, though unicellular are very interesting forms, because of their great diversity in form and wonderful symmetry. Some of them are indeed the most beautiful microscopic objects. These Algae occur as floating forms in great abundance in pools, ponds and margins of lakes. Their cells consist of two symmetrical halves separated usually by a small constriction. In general outline some of them are rounded, as in

Cosmarium, some stellate, as in *Micrasterias* and other are cylindrical and lunate, as in *Penium* and *Closteriun* Some of the Desmids such as *Staurastrum*, *Micrasteria* and *Euastrum* present the most complicated forms o outline.

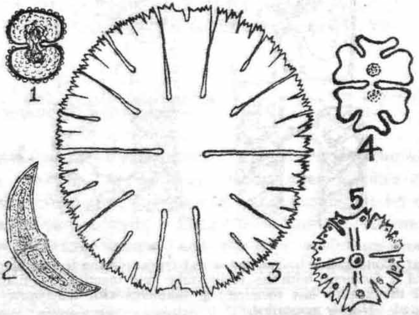


Fig. 248.—Desmids. 1, *Cosmarium* ; 2, *Closterium* ; 3, and 5, *Micr sterias* ; 4, *Euastrum*. All highly magnified.

The protoplasts are provided with a single nucleus i each individual and it is usually lodged in the middle c the cell. The chloroplasts are large and are of som definite form, conforming to the general shape of th individual. They are either central or parietal i position. Pyrenoids occur in them.

Desmids usually propagate themselves vegetatively b

simple cell division. Sexual reproduction is occasionally met with amongst them. Two individuals approach each other and they remain close together by the formation of a mucilaginous sheath. The protoplasts from these two cells escape, fuse and form a zygote. No tube is formed between the two individuals. The conjugating gametes cannot be distinguished from each other. The zygospore forms three coats, the first or innermost being of cellulose, the second thick and brownish and the third external one warty or spiny. Owing to these outgrowths, zygospores are generally very striking.

Species of *Cosmarium*, *Euastrum* and *Staurastrum* are commonly met with in ponds and lakes.

Oedogonium Link :—Several species of *Oedogonium* are found in ponds, puddles and in running water also. Like *Ulothrix* these species also consist of unbranched simple filaments with well-marked haptera or organs of attachment at the base when young, although these filaments float freely when adult. The filaments vary in thickness very much according to the species.

The filaments are usually rigid, uneven in thickness and without any mucilaginous sheath. Each filament terminates at the apex either by a rounded cone or by an attenuated process. The cells composing the filaments are all cylindrical, with the apical part of each cell slightly wider than the basal part, thus showing the distinction between the base and the apex even in the cells. The cell wall of cellulose possesses a cytoplasmic layer adhering to it, and a nucleus is imbedded in the centre of the cytoplasm. In the cytoplasm of every cell, there lies peripherally a reticulate chloroplast, and in this a number of pyrenoid bodies occur.

The *Oedogonium* filaments grow in length by the

division of the cells of the filament. But the cell divisi is of a kind quite characteristic of the genus. In ma species of *Oedogonium* we find sometimes a number transverse striations in the upper parts of some of tl cells forming the filament. These striations or the s called "apical caps" are due to repeated cell divisio taking place in the same cell. All the cells except tl basal cell are capable of division. In a cell which about to divide, the nucleus at first undergoes divisic into two daughter nuclei, and, at about the same tim a ring-like thickening of cellulose is formed inside tl cell wall at the apex of the cell. This cellulose cushic is connected with the cell wall both above and belo Exactly opposite to the thickening in the cell wall, tl cell wall of the cell becomes torn all round externall The slit thus caused all round is closed by the inte calary growth of the ring-like cushion into a cell wa membrane. Between the two daughter nuclei a tran verse septum is formed which extends to the outer ce wall dividing the cell into two. By the intercala growth of the cushion, now forming a portion of the ce wall of the newly formed cell, the upper part of the o wall is pushed upwards and this persists as an "apic cap." The new cell formed in this manner is as it we intercalated between the upper and lower portions the cell in which cell division has occurred. This proce of cell division is repeated immediately below the se tum at the upper end of the cell, and so the upper portio persisting look like caps placed one over the other.

Propagation is effected in *Oedogonium* both by asexu and sexual methods of reproduction.

Asexual reproduction takes place by means of zoo pores. The protoplasm of a cell of the filament, whic is about to form a zoospore, undergoes rejuvenescen

and gradually contracts away from the cell wall. In the meanwhile the cell wall gets ruptured transversely at or near the upper end into two very unequal halves. The upper small portion of the cell is lifted up like a lid and the *rejuvenated protoplast*, now transformed into a zoospore and enclosed in a delicate *hyaline* vesicle, escapes through the opening.

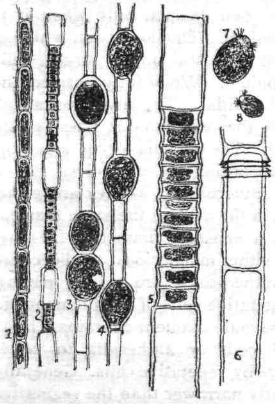


Fig. 249.—*Oedogonium*. 1, filament; 2, antheridia in a filament; 3 and 4, oogonia; 5, antheridia; 6, cell dividing; 7, zoospore; 8, antherozoid. 1, 2, 3 and 4, slightly magnified; 5, 6, 7 and 8 highly magnified.

The zoospores are rather large and unique. In shape they are rounded or pyriform. The anterior end is colourless and bears a circle of numerous short cilia. In some species a *red pigment* spot also is present at the anterior end. The zoospore moves about for a short time and then attaches itself to the substratum by its hyaline end, losing all the cilia. The attached end developes into a hapteron and a cell wall is formed and then it grows into a filament.

Sexual reproduction in Oedogonium is of a very high type and the specialisation of the male and the female organs is greater than in any other Algae, except in

Characeae. In this specialisation it approaches Bryophyt The female sexual organ or oogonium is formed from vegetative cell. The cell which is destined to becor an oogonium divides into two unequal cells when it about to become an oogonium. The lower cell which smaller is the stalk-cell and the upper larger cel developes into an oogonium. When fully formed th oogonia are spherical or ovoidal. The large sexual ce or the female gamete in the oogonium is passive an never leaves the filament. The oogonia occur singly in a series of 2 or more according to the species.

The male gametes or antherozoids, as they are som times called, are formed in the cells in the same filamer as the oosphere, or in a separate filament. In othe words, *Oedogonium* is either monoecious or dioeciou The cells that produce antherozoids are usually narro and smaller than the vegetative cells of the filament. I the dioecious species, the male filament contains a larg number of these small cells or antheridia in serie interrupted here and there by vegetative cells. Generall these filaments are slightly narrower than the vegetativ and female filaments. In each antheridial cell tw antherozoids are formed. Antheridia are formed by cel division of the ordinary vegetative cells, and the firs dividing wall is always near the apex of the cell, in th case of monoecious species. In an antheridium the tw antherozoids that are formed lie one above the other i some species, as the division of the protoplast is trans verse, while in others in which they are formed by vertical division of the protoplast they will remain sid by side.

The antherozoids also escape, like the zoospores with vescicle of hyaline membrane, swim about for some tim and then they penetrate an oogonium through a

aperture in the cell wall existing near the anterior end of the oosphere. After fertilisation the oosphere changes into a zygote or oospore in which a thick firm wall is soon formed. Ordinarily these bodies germinate only after a definite period of rest. They do not germinate and grow into plants immediately, just as zoospores do.

In some species of *Oedogonium* what are called "dwarf male plants" occur near the oogonia or on them. In the cells of these dwarf males antherozoids are formed and they get into the oogonium and fertilise the oosphere. These dwarf male filaments develop from spores called **andro-spores** which are intermediate in size, between zoospores and antherozoids. The androspore swims about and then settles down at or near the oogonium by its colourless ciliated anterior end and then grows in to the dwarf male plant. The androspores are formed in short cells of the filaments either singly, or in chains.

Botrydium Wallroth :—So far, we have been considering the filamentous forms of Algae. *Botrydium* may be taken as a typical example of the coenocytic forms of Algae. This remarkable plant occurs in groups as green blobs on wet clayey ground of dried up pools, ponds and ditches.

The plants are coenocytes consisting of green aerial portions and colourless under-ground parts. The aerial portion of each plant is a balloon, or pear-shaped body about the size of a pin's head (1 to 2 mm.) with a layer of cytoplasm close to the cell wall within which are imbedded chloroplasts in several layers. The nuclei are found inside in the cytoplasm next to the chloroplasts.

The underground part is colourless and consists of numerous branches formed by repeated forking. These

branches also contain protoplasmic contents. We fin in this plant a kind of physiological differentiatio the upper aerial portion doing the work of nutritio and the underground part that of absorption.

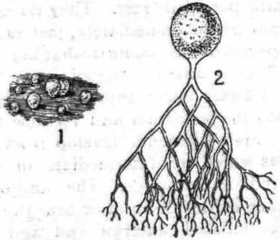


Fig. 250.—*Botrydium.* 1, group of plants of natural size; 2, a sing complete plant magnified.

Propagation is effected in this Alga chiefly by mear of spores, motile or non-motile, formed asexually. Whe the plant is submerged, a very large number of zoo spores are formed within the upper aerial green portio of the plant, and they escape through an opening at th top. Each zoospore is a small ovoid body with tw chloroplasts and two unequal cilia. If the plants a merely wet, but not submerged, the spores round then selves off as non-motile bodies, each of which ca grow into a new plant. Under conditions of drought th protoplasmic contents of the aerial portion recede in the rhizoids and there form in each tube a number small cells surrounding themselves with new wall These cells develop into zoospores if submerged water, but when only wet grow into the *Botrydium* plar When dry they behave like resting spores. Sometim

n some plants the contents of a tube of the underground ortion reach the end of the tube and there change into single large spore covered by thick cell wall and a heath of mucilage.

CHAPTER XIX

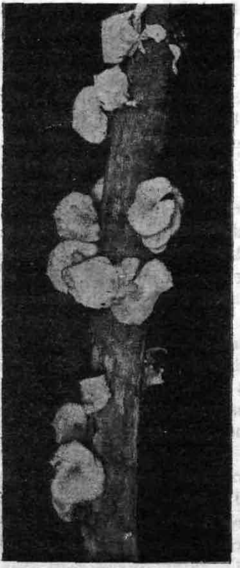
FUNGI AND BACTERIA

THERE are many kinds of Fungi such as the Moulds, Mildews, Rusts, Smuts, Mushrooms and Toadstools. All plants of this group are devoid of chlorophyll and, therefore, they cannot manufacture within themselves any organic material. They have to derive their organic nourishment from some source outside their own body. In other words, the Fungi are heterotrophic in their mode of nutrition. For instance, some Fungi obtain their food supply from some other living organism, a a plant or an animal. The plant which supplies the nutritive material is called the **host** and the dependent Fungus-plant is termed a **parasite**. But sometimes Fungi depend for their food on dead remains of plants or animals, or on products derived from these sources. Such Fungi are called **saprophytes.**

It must be noted that, although irregular nutrition is met with in a few flowering plants, Fungi are the only plants whose leading character is irregular nutrition, and these form a distinct group by themselves.

The parasitic mode of living on the part of Fungi must necessarily affect other living plants and cause immense damage to them. In nature such damages are common enough. But the attack and the damage are extensive only when plants of the same species are massed together, as when they are grown as crops. So it is only then that these Fungi become very conspicuous and attract our attention. Since Fungi are responsible for many diseases in plants, the study of these plants is important from an economic

oint of view. For controlling the various diseases aused by Fungi, a knowledge of these plants as regards eir mode of life and reproduction and how they deal with their hosts is essential. Without this knowledge it is not at all possible to check the disease from spreading, and much less to eradicate the disease. So now-a-days a considerable amount of attention is bestowed on the study of the life-histories of the Fungi. The branch of study specially dealing with the Fungi is called Mycology.



'ig. 251.—A Saprophytic Fungus growing on a dead piece of wood.

In their habit, form and mode of living the Fungi are most diverse. These plants show the greatest amount of resource, especially in the matter of the acquisition of their food. Considering the variations of their host plants and the necessity of obtaining organic matter for food anyhow, it cannot but be so. It is this pecial feature that makes it most difficult to combat the avasion of these plants by preventive measures.

However varied the Fungi may be in their external

form and size, the structure of their thallus is very simple. The plant body in every case consists of simple or unbranched filaments or threads called **hyphae**. The whole of the hyphae constituting the body of a Fungus-plant is often termed its **mycelium**. In many Fungi the filaments grow singly and separately without being massed together, as in Moulds and Mildews. The higher Fungi such as Mushrooms and Toadstools have massive bodies in which the hyphae become so closely and intimately appressed together as to form a definite tissue, as to be called pseudo-*parenchyma*.

Propagation is effected in the vast majority of Fungi, by means of asexual reproduction in which a prodigious number of spores are usually formed. These spores are variously named according to their mode of origin. In some the spores are formed inside a sac or sporangium, and the hyphae bearing these sporanges are called **sporangiophores**. The spores are not enclosed, but are formed in chains at the ends of erect hyphae, and these spores are called **conidia** or **conidiospores** and the hyphae bearing these chains, **conidiophores**. There are also spores called **basidiospores** (or **carpospores**) as they are formed on special bodies called basidia. The spores are best adapted for life in air. Some Fungi, however, have the method of sexual reproduction, in addition to the asexual mode. The sexual method is only a rare event, and it is confined to a few lower Fungi such as Moulds.

The Fungi are grouped into two subdivisions, one in which the hyphae are not septate i.e., divided by ransverse partitions into cells, and another in which the hyphae bear division walls. The former constitute the **Phycomycetes** and the latter **Eumycetes**.

As regards the origin of Fungi, it is suggested by some that the Phycomycetes may have originated from the Siphoneae and the Eumycetes from Red Algae. Whatever view we take, it is certain that the Fungi have originated along more than one line of ancestry. Further Fungi seem to have existed from the earliest geological period.

As typical examples we may study some of the common Moulds, Rusts, Smuts and Mushrooms.

MOULDS

Rhizopus nigricans:—This Fungus is cosmopolitan in its distribution. Pieces of moistened bread and fruits kept under a bell-jar in air saturated with moisture become mouldy. After a day or two a white flocculent mass with a cob-webby appearance forms on the pieces of bread. This fluffy mass represents the thallus or plant body of the Fungus. Generally on pieces of bread thus kept in a moist atmosphere, several moulds may appear, and the first to appear is the Fungus *Rhizopus nigricans*. If the pieces of bread are kept longer under the bell-jar, *Rhizopus* is succeeded by two more Fungi, *Penicillium* and *Eurotium*.

This fluffy mass, which is also called the mycelium, consists of fine and coarse transparent threads running in all directions, some horizontally, a few vertically downwards and others vertically upwards into the air. As already stated the mycelium which appears first is that of *Rhizopus nigricans*. Of the hyphae of this Fungus found growing on bread, the horizontally creeping filaments are usually stouter and these give rise to the finer branches which penetrate the substratum in al directions. The finer branches of the mycelium traversng the interior of the piece of bread in all directions isl

able to do so as they go in search of food. The erect hyphae end in rounded bodies which are sporangia, and so these erect threads are sporangiophores. If a culture of this Fungus is obtained on a piece of glass, then we can well see the nature of the mycelium which consists of numerous branches of nonseptate hyphae regularly branching and bearing also erect sporangiophores. (see fig. 252).

In this plant we just find the beginnings of division of functions. The horizontal primary hyphae grow on the surface of the substratum and cause the further spread or extension of these threads all over the substratum. The fine branched filaments that grow downwards into the substance of the bread in all directions absorb the food materials, after altering the colloidal substances

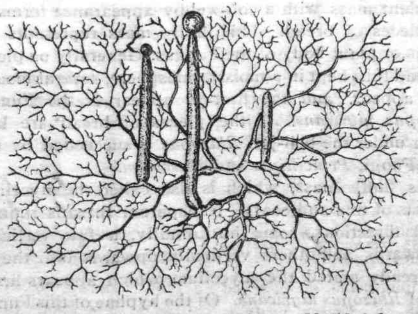


Fig. 252. Mycelium of *Rhizopus nigricans.* (Modified from Kny's diagram.) Magnified.

into soluble forms. The somewhat thicker hyphae arising later, from the horizontal branches, from about the same place at which the groups of threads growing

vertically downwards start, grow erect into the air and develop sporangia at their free ends.

The hyphae are filled with vacuolated protoplasm, and it adheres peripherally to the cell wall and forms a regular peripheral layer. As there are no septa, the protoplasm is continuous throughout the mycelium. Further, there are a large number of nuclei in the cytoplasm. Hence this Fungus is coenocytic.

When the Mould *Rhizopus* is young it is fluffy and white, but as it gets older it becomes brownish and powdery in appearance, and a large number of distinctive somewhat black dots also appear. These dots are all sporangia.

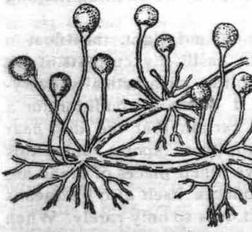


Fig. 253. Sporangia of *Rhizopus*. Slightly magnified.

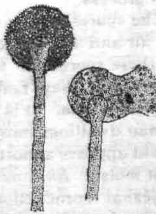


Fig. 254.—Sporangia of *Rhizopus*. Highly magnified.

Propagation is effected in this Fungus mostly by means of spores formed asexually. As soon as the mycelial threads have grown to a certain extent and have reached considerable size, erect branches or sporangiophores begin to appear.

The free ends of the hyphae that grow erect, swell and a cross-wall is formed below the swelling cutting off

this swollen portion from the rest of the thread. This round swollen tip of the erect hypha grows into a large globular body which later developes into a spore-sac or sporangium. When the sporangium is in the course of formation, we see sometimes the protoplasm moving very rapidly towards the tip from the lower portions of the erect hypha. In a mature sporangium, instead of protoplasm we find a mass of spores embedded in a mucilaginous substance. The cross-wall, in a mature sporangium gets pushed in forming a projecting mass called the columella. The sporangial wall when mature will be found to have externally small radiating crystals of calcium oxalate. The spores escape by the bursting of the sporangial wall, the mucilage by its swelling helping this process.

The spores being very minute and light, they float in the air and are carried about easily by currents of air. So these spores are found in the air practically everywhere, and they remain in a dormant condition for a very long time. It is almost certain that the dust near human dwellings must contain these spores, since this Mould appears almost always when pieces of bread are kept moist. *Rhizopus* reproduces itself also by means of sexual reproduction, but it does so only rarely. When the hyphae of two distinct mycelia developed from two different spores growing in the same medium come into close proximity to each other, short club-shaped branches arise on the adjacent hyphae and these grow towards each other until the club-shaped bodies meet at their tips. Soon after, a transverse wall developes in each of these club-shaped ends cutting off the protoplasm from the rest of the branch. At the point of contact the cell wall dissolves and the two protoplasmic masses of the tips fuse into a single mass. These two masses of proto

ılasm are really sexual cells and the union is similar to he process of conjugation occurring in *Spirogyra*. The nass of protoplasm resulting from the fusion developes nto a zygospore, which after a period of rest germinates ınd gives rise to a sporangiophore.

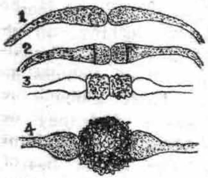


Fig. 255.—Sexual reproduction in *Rhizopus*, showing the different stages of conjugation. Highly magnified.

The bread Mould is saprophytic in its mode of nutrition. There are also other non-septate Fungi which are parasitic and so do considerable damage to the host plants. Species of *Pythium* and *Phylophthora* are parasitic Fungi. The former attacks the seedlings of Mustard and Cress and the later infests the potato plants, palms and other plants of economic importance. The spores of *Pythium* and *Pytophthora* are motile. The sexual organs are differentiated into oogonia and antheridia.

Penicillium also is another Mould appearing on bread along with *Rhizopus*. As this Fungus forms patches which turn blue-green in colour when old, it is easily distinguished from other Moulds. When young the mycelium appears as a white patch, and, as it grows, becomes first pale blue, and then dull-green, the change of colour starting at the centre of the patch and spreading to the outside.

The mycelium of *Penicillium* consists of hyphae that are slightly thinner than those of *Rhizopus*, but are septate. The spores are not formed in a sac, but are developed in a different way. The erect hypha bears at its free end a number of branches, giving it a brush-like

appearance. All the branches formed at the end of the hypha arrange themselves parallel to one another and vertical to the mycelium. On these terminal branches spindle-shaped small segments called **sterigmata** are formed. At the tip of a **sterigma** a minute globule is formed at first, and then a second one pushing up the first and the second and so on, until a chain of globules are formed. These globules are really spores and they are called **conidia** or **conidiospores**. The hypha bearing these conidia is called **conidiophore**. The older conidia forming the outer end of the chain have a blue colouration in their walls which confers the characteristic blue colour to the naked eye.

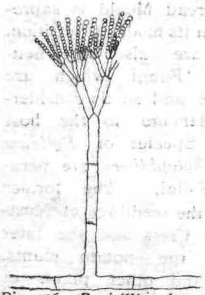


Fig. 256.—*Penicillium* showing the conidiophore and conidia. Magnified.

Penicillium resorts at times to sexual reproduction. Two short branches arise from the mycelium and these coil round one another spirally. Of these one is the oogonium and the other an antheridium. From this coil short branches called **ascogenous hyphae** grow out in every direction. The hyphae supporting the spiral coil also give rise to numerous threads which grow up over the ascogenous hyphae and form a compact cover. The walls of the outer layers become thickened and dark yellow in colour and form a hard resistant coating or rind. After several weeks number of tube-like structures called **asci** arise from ascogenous hyphae. Each ascus or tube contains eight **ascospores**. The ripe **ascocar**

kes about six months to develop and become mature, d it bursts open to set free the ascospores.

Along with *Penicillium* and later than that, another ould may appear on pieces of bread moistened and pt in damp places. This mould is rather coarser in eir filaments and is of an olive green colour. Minute llow specks may appear upon the mycelium later. his Fungus is *Eurotium* (*Aspergillus*). Like *Penicllium* these bear conidiophores which have at their free

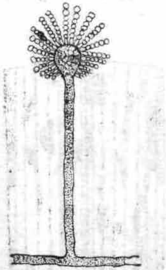


Fig. 257.—Conidiophore of Eurotium. Highly magnified.

nds chains of conidiospores radiating on all sides f a globular end of the erect hypha. Sexual reproducion also occurs and a carpogonium is formed, from which ascospores enclosed in asci arise.

RUST-FUNGI

A very large number of Rust-Fungi are known to live s parasites on the shoots of many plants. Some of them re very highly specialised and so they are parasitic

only on certain genera or species of plants. The mycelium of these Fungi is internal and the hyphae which are septate traverse the intercellular spaces and the cells of the tissues in the leaves and stems of host plants. As the Rust-Fungi obtain the nourishment they require from their host plants, the latter suffer very much, although they do not succumb completely.

The most familiar of the Rust-Fungi is *Puccinia* which causes the Rust disease in cholam (*Andropogon Sorghum*), wheat (*Triticum vulgare*) and other cereal crops.

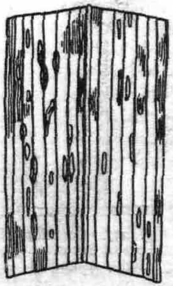


Fig. 258.—A bit of cholam leaf with Rust-spots.

The appearance of red or rusty spots on the leaves and stems of *Andropogon Sorghum* plants is an indication that these plants are infested with the Rust-Fungus *Puccinia purpurea*. The hyphae of this Fungus traversing the tissues of the leaves and the stems come out through the intercellular spaces and reach the surfaces of the leaves or stems of the host plant, just

beneath the epidermis. At the ends of these hyphae spores are formed and they are grouped in clusters forming the red spots or pustules. So long as the spores are immature the pustules are roofed over by the epidermis, but as soon as they are ripe, the epidermis bursts open exposing the spores. When mature these spores are reddish, unicellular and with rough external surface. They are called **uredospores**, and sometimes summer spores, since they are formed first and usually in summer. The protoplasts of these spores and the cells of the hyphae are binucleate. As the uredospores are exposed in the ruptured pustules they are carried by winds and, if they fall on leaves, they germinate and the hyphae get into the interior through the stomata. So

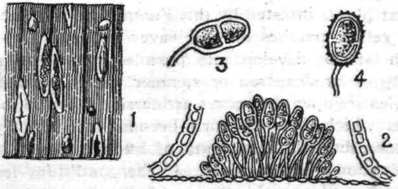


Fig. 259.—Uredospores and teleutospores of *Puccinia purpurea*. 1, bit of a leaf with pustules of spores; 2, vertical section of the pustule showing teleutospores; 3, teleutospores; 4, uredospores. 2 and 4 highly magnified.

by means of these spores the disease may spread quickly and widely over vast areas of *Andropogon Sorghum* crops.

During the earlier part of the life of the host plant the pustules are composed of uredospores only. But later on when the host plants have grown fully another kind of spores called **teleutospores** is also found mixed up

with uredospores. In *Andropogon Sorghum* plants, when they are advanced in growth, the pustules appear darker in colour and they consist almost wholly of teleutospores. The teleutospores are two-celled with thick, smooth cell walls.

Puccinia is a very interesting parasitic Fungus with a complicated life history. So far as the Rust-Fungus *Puccinia purpurea* is concerned, its life history is simple, its spread being brought about chiefly by uredospores. How the cholam plants get infected by this Fungus and what happens to the teleutospores and what part they play in the life cycle of this Fungus are problems awaiting solution.

The life-history of the species *Puccinia graminis* causing the Rust disease of wheat is now well-known. Wheat plants infested by this Fungus show in June and July yellow patches on the leaves between the veins, which later on develop into pustules, consisting almost wholly of uredospores or summer spores. When the pustules are open the spores are carried by wind to other plants which in their turn become infected by the entrance, through the stomata, of hyphae formed by the germination of uredospores. If the conditions for germination are favourable the spores germinate extensively and the wheat crop in all the fields may get infected. Later on in autumn when the wheat plants are well-grown the pustules are composed wholly of teleutospores, although in some of the pustules a few uredospores may be found, especially in those formed earlier. The teleutospores, by reason of their having thick walls, are able to tide over unfavourable conditions during winter. As a matter of fact, they do not germinate immediately. We may consider teleutospores as representing a stage in the life history of *Puccinia graminis* intended to

enable it to live through the unfavourable season, winter and hence these spores are also called winter-spores. In all probability teleutospores remain in the ground or on some other substratum until the spring time. At spring time, as soon as some moisture and warmth are available the teleutospores germinate, and at first a short tube or hypha issues from these spores, which in its turn forms at its extremity four distal cells by segmentation. In the hypha before segmentation the two nuclei fuse into one and then by reduction division four nuclei arise which are later found in the four cells, one in each. From each of these four cells small stalks or sterigmata arise bearing spores. These bodies bearing the sterigmata are called **basidia** and the spores **basidiospores**. It is interesting that the hyphae resulting from the germination of teleutospores are saprophytic in their mode of nutrition.

The basidiospores do not infect the wheat plant. These spores infect the leaves of Barberry. The hyphae get through the stomata into the interior of the leaves and these branch and form a large number of threads. The affected parts of the leaf appear as thick patches. After a time small flask-shaped structures appear on the upper surface. Inside these some small rounded bodies called **spermatia** appear. They are non-functional and are probably male organs. On the lower surface of the leaves of Barberry cup-like structures called **aecidia** are formed as the result of the infection of the fungus. An aceidium consists of an outer sheath and a number of erect hyphae rising from the base of the cup. The filaments produce chains of small round spores. These are called **aecidiospores**. The oldest spores are those that are found at the distal end of the hyphae and as the aecidia are turned downward, these spores are shed

in succession and they infect the grasses and wheat plants again.

Thus we see that *Puccinia graminis* produces four distinct kinds of spores, the uredospores and the teleutospores developing on the wheat plant, the basidiospores forming on threads that are saprophytic and the aecidiospores developing on the leaves of the Barberry quite a different host.

It is an interesting fact that the basidiospores and the mycelia living within the Barberry leaf alone contain nuclei that are haploid in their protoplasts, whilst aecidiospores, mycelia formed from them, uredospores and teleutospores have diploid nuclei in their protoplasts.

In Europe in the eighteenth and the nineteenth centuries people had vague notions that "Rust" or "Blight" of wheat crops was somehow caused by Barberry, but they were not aware how Barberry was responsible for the spread of this disease, until De Bary worked out the life history of *Puccinia graminis* and conclusively showed that the rust on the Barberry plant and that on the wheat plant are only different stages of the same Fungus, and that two different kinds of host plants are necessary for this parasitic Fungus to complete its life cycle.

SMUT-FUNGI

Smut-Fungi also, like Rust-Fungi, are parasitic particularly on grasses. Some of them produce in the inflorescence of cereal crops the disease known as Smut. For example, in *Andropogon Sorghum* plants we find in the ear-heads in the place of grains some tumour-like structures when these plants are attacked by the Fungi *Tolyposporium filiferum* and *Cintractia Sorghi-vulgaris.*

The tubular tumor-like structures found in the ear-heads are full of black powder, which is really a mass of spores.

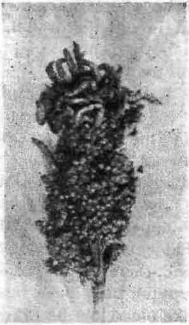


Fig. 260.—A ear-head of Cholam (*Andropogon Sorghum*) bearing smut spores of *Tolyposporium filiferum*.

In the Smut-fungi the brand spores found as black powder in the inflorescence in the place of grains undergo a period of rest usually in the soil or other substratum. They then germinate, and each spore gives rise to a short mycelial tube called promycelium which becomes divided into two or more small portions called basidia, and these produce spores, called basidiospores. Sometimes, under very favourable conditions of nutrition, the promycelium, instead of breaking up into basidia and developing basidiospores, grow rapidly and branch profusely and finally divide into a large number of conidiospores.

The basidiospore or the conidiospore germinates and a hypha is formed which penetrates the young seedlings and gets started in the tissues of the seedling. By further growth and extension the hyphae go as far as the apical cone where the inflorescence takes its origin. The host plants though infected grow on, as though quite healthy, without showing any symptoms of disease. With the growth of the host plant, the mycelium of the Fungus also grows and invades definite regions, though not all the parts of the plant. At the time of the flowering of the host plant, the hyphae get into the ovaries anc divert the food material for its own use, instead of allow ing it to be used in the formation of the grain. Ir consequence of this invasion, the ovaries become swollei and distorted and appear as tumour-like outgrowths All the hyphae that enter the ovaries become changei into brandspores and, therefore, in the ear-heads we fin sacs of spores occupying the place of the grains.

Infection may take place by the brandspores lodgin on the grain or the glumes, or the hypae, formed by th basidiospores or the conidiospores germinating in th soil, may get into the seedlings.

Species of *Ustilago* also attack the cereal crop *Ustilago sorghi* often invade cholam plants and *Setari italica* is attacked by *U. Crameri* and other millets b *U. panicum miliacei.*

Both the Smut-Fungi and the Rust-Fungi belong the class of Basidiomycetes.

MUSHROOMS

Most of the large Fungi such as the Mushroom Toadstools and Puff-balls belong to the Basidiomycete What we call the Mushroom, Toadstool and Puff-b are really the fructifications of Fungi. Although there

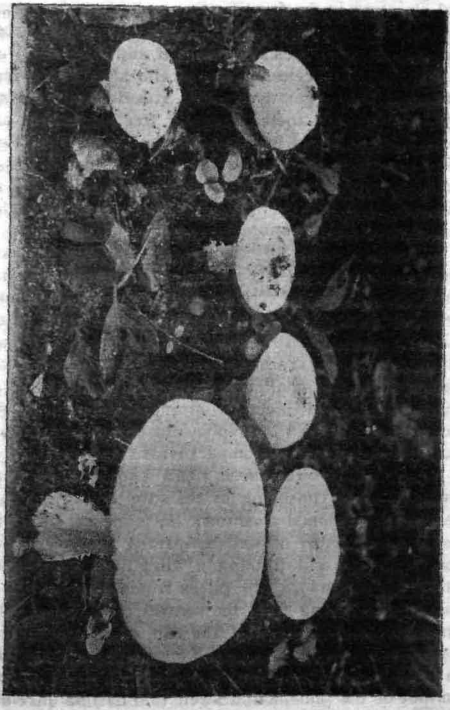


Fig. 261.—Mushrooms (*Armillaria*).

such a great diversity in the outward form and the inter nal structure in the fructifications, all these Fungi ar alike in their spore formation. In all these Fungi basidi bearing basidiospores are produced, and hence they ar called Basidiomycetes. The mycelia after a consider able amount of vegetative growth, give rise to compacte hyphae here and there and their free ends swell an become club-shaped bodies called **basidia**. Each basi dium produces two, four or rarely eight slender processe called **sterigmata**, and each sterigma swells at its ti into a round shape. Later on this rounded part detache itself as the **basidiospore**.

The fructification of the Fungus which we usuall call a mushroom consists of a stalk called the **stipe** an an umbrella-like cap termed the **pileus**. These bodie really spring from the mycelium which vegetates in th substratum on which it feeds. The mushroom fungus i either parasitic or saprophytic. The spore-bearing cap appear at first as small white rounded small buttons o the under-ground mycelial strands. These rounde bodies are composed of hyphae closely interwoven an packed so as to form a compact mass.

By further growth these small knobs change int the mushroom consisting of the stipe and the pileus In a well-developed mushroom the stipe consists of very large number of well-compacted hyphae runnin longitudinally and forming a kind of pseudo-paren chyma. We find in the pileus a number of **gills** o lamellae extending from the central portion where th stalk joins to the edge of the cap, like the spokes o a wheel. The gills consist of a mass of hyphae runnin in all directions. Some of these hyphae come out at th surface of the lamella and swell into basidia or remai sterile. The central core of the gill is called the **tram**

and the external portion consisting of the free ends of hyphae which have either become basidia or sterile paraphyses constitute the **hymenial layer**. If a vertical section of the gill is examined under the high power of a microscope all the parts will be clearly seen (see fig 262). The basidia in *Agaricus campestris* or the

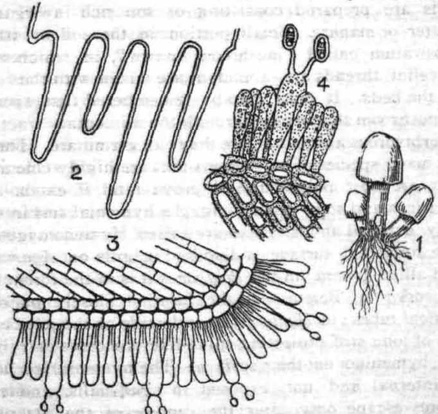


Fig. 262.—Parts of the mushroom and their structure.
1, young mushrooms; 2, gills; 3, a lamella with trama and spores; 4, basidia and spores. 1, natural size; 2, and 3, slightly magnified; 4, highly magnified.

edible mushroom possesses only two basidio-spores in a basidium.

If a ripe pileus with its gills is placed on paper, after some hours the basidiospores would be found to have fallen on the paper in radiating lines. If the spores are black the paper used must be white and, if they are

white black paper must be used, as only then the lines of spores would be visible due to contrast. Mushrooms are propagated only by their basidiospores and no sexual mode of reproduction is known amongst them.

The mushroom *Agaricus campestris* is largely eaten and so it is extensively cultivated in many countries. Beds are prepared consisting of soil rich in organic matter or manure. Small portions of the soil or other substratum called "mushroom spawn", in which the mycelial threads are abundant are mixed with the soil of the beds. It must also be remembered that spores of mushroom should pass through the alimentary tract of a herbivorous animals before they can germinate. There are many species of mushrooms that are highly coloured that are most poisonous and prove fatal if eaten. In Agaricus and some other Fungi the hymenial surface is fully exposed and so these are called Hymenomycetes. The hymenial surface is disposed in gills on *Agaricus* and allied genera; in the *Polyporus* it is in the form of a network; in Boletus in the form of closely packed vertical tubes; in *Hydnum* the underside of the pileus is full of long stiff projecting spine-like processes carrying the hymenium on their surface. The hymenial surface is internal and not exposed in Puff-balls, and the spores escape only after the rupture of the external membrane.

BACTERIA

Bacteria are the smallest of plants, appearing even under the highest powers of the microscope as minute dots or rods. Some believe that there may be bacteria so minute that they cannot be seen even under the highest powers of the microscope. A large number of species of Bacteria flourish everywhere over the whole earth.

They occur in water, in the atmosphere, in the soil and in the bodies of plant and animals dead or living.

In structure these plants are extremely simple, consisting of a very thin delicate cell wall and protoplasm not differentiated into cytoplasm and nucleus. Most of the species are unicellular, although a few assume filamentous forms. These organisms, like Fungi, live either as parasites or saprophytes, since they are devoid of green colour.

The chief striking features of Bacteria is their power of causing chemical changes in the substances with which they come in contact. Many species of bacteria change the nature of the organic substances in which they grow by means of enzymes. The breaking down of carbohydrates is called fermentation and the decomposition of nitrogenous substances of vegetable or animal origin is termed putrefaction. In nature the accumulation of debris of organic matter resulting from the death of plants and animals is due to the fermentation and putrefactive changes brought about by Bacteria. All the complex substances are transformed into simpler stable substances by the action of these minute plants.

Propagation in Bacteria is mainly by means of cell division by fission. In some species, such as the hay-bacillus, spores are formed inside the cells and these are called endospores. But such endospores are not common. Multiplication by fission is so rapid that in a day several millions of them may be formed. Amongst Bacteria we have both useful and harmful ones. For instance, the formation of curds in milk and the ripening of butter are due to the action of Bacteria. There are Bacteria which change ammonia into nitrites and then nitrites into nitrates. Certain soil bacteria are able to form nitrogen compounds by utilising the nitrogen of the

atmosphere. We should also mention here the bacteria found in the root nodules of leguminous plants, as they also utilise free nitrogen for making nitrogenous compounds for their use.

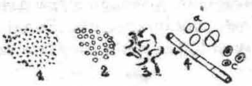


Fig. 263.—Bacteria. 1, soil bacteria ; 2, pus bacteria; 3, comma bacilli of cholera; 4, hay bacillus. These are very highly magnified.

We have a host of Bacteria causing disease both in plants and animals. As examples of pathogenic Bacteria causing diseases in man, we may mention those responsible for cholera, plague, tuberculosis, typhoid and tetanus. The swellings seen in the leaves of *Pavetta indica* and other Rubiaceous plants are due to Bacteria living symbiotically in the leaves. The ring disease in potatoes and the bud-rot in some palms are brought about by Bacteria.

Though very minute in size, the Bacteria present variations in their shape and they are classified on the basis of their shapes. All unicellular forms are treated as one group called **Haplobacteria** and the few filamentous forms are put under a second group termed **Trichobacteria**. Amongst Haplobacteria we have some with cells rounded, some with rodshaped cells and others curved or spiral. They are termed *Cocci*, *Bacilli* or *Bacteria*, *Vibrios* and *Spirilla*.

Bacteria are generally made out in cultures by their general external appearance only. Some of them grow

patches and these patches are different in their shapes d even in shades of colour, according to the species. › in the laboratories they are distinguished one from e other even by the external appearance.

CHAPTER XX

BRYOPHYTA

LIVERWORTS and Mosses constitute the group Bryophyta. The number of species of Bryophyta are large and they are wide-spread in all lands, except where there is persistent drought. The green Thallophytes are essentially aquatic in their mode of life and none of them are found in sub-aerial vegetation. On the other hand, the Bryophyta are adapted for sub-aerial life on land. The structure of their vegetative organs are best fitted for life on land, although they have to depend for their *fertilisation on external fluid* water. This necessitates their growing in habitats where fluid water would be available, at least during the time of fertilisation. We have to consider the plants of this group as the most primitive forms of vegetation on land.

Compared with Thallophyta these plants are higher in organisation. The sexual organs are extremely simple in the former, but not so in the latter. As Liverworts and Mosses live on land the egg-cell which is a primordial cell has to be protected against the drying influence of the air. As a measure of protection the *ovum* or the egg-cell is retained within the tissues of the parent, and an archegonium is formed. It must be noted that the archegonium serves both the purposes, namely, protection and nutrition of the ovum or the egg-cell. For the survival of the species this is very essential. The antheridia which produce the *spermatozoids* (or *antherozoids*) are also well protected and nutrition is ensured.

The most striking feature of this group is that every

species has in its life-cycle two distinct generations one alternating with the other. The plant which is conspicuous is the sexual generation producing the sexual organs **archegonia** and **antheridia**. The *sexual generation* or the **gametophyte** is followed by the next generation, the spore-bearing generation called the **sporophyte**. In all Bryophytes it is only the gametophyte that is capable of an independent existence and the sporphyte is always dependent on the gametophyte for its nutrition. Another interesting fact is that the chromosomes in the nuclei of the sporophyte are twice as many as are found in the gametophyte. In other words, the gametophyte is the haploid generation and the sporophyte is the diploid generation. When fertilisation takes place, by the fusion of the nuclei of the sexual cells the chromosomes become doubled, and the number becomes half by reduction division when the spores are formed.

The Bryophyta is comprised of the two classes (1) Liverworts or Hepaticae and (2) Mosses or Musci and they may be differentiated one from the other by the following characteristics :—

The Liverworts have in most species a dichotomously divided, dorsiventral flat thallus, although a few species are foliaceous. In the sporophyte no columella is developed, and along with spores elaters are formed.

In the Mosses the plant is differentiated into a stem with leaves spirally arranged on it. No elaters are formed, but a columella is always formed in the sporophyte.

LIVERWORTS (HEPATICAE)

Liverworts usually flourish in beds of rivers, in ditches, on rocky ledges splashed by sprays of water, and, in fact, in any place where there is enough moisture. A

few species, however, live in dry habitats such as the bark of trees, on rocks or on the ground. They do not generally attract our attention very much as they flourish in nooks and corners. Further they are of no economic importance.

As an example of Liverworts we may study the cosmopolitan species *Marchantia polymorpha* since it is easily obtainable in all stages of development. The predominant generation or the gametophyte which is usually called the Liverwort has a plant body consisting of deeply lobed, dichotomously branched, dorsiventral green flat plates of about three-quarter of an inch width. In the flat plate or the thallus there is a midrib which is not conspicuous. *Marchantia* forms large continuous patches covering the ground like a carpet, and the older portions of the plant die, leaving the younger parts to develop as independent plants.

Fig. 264.—Male and Female plants of *Marchantia polymorpha.*

The green dorsal surface of the thallus presents to the naked eye a number of rhombic areas, each of which being perforated by a central air-pore. The diamond-

haped areas are really so many chambers, separated rom one another by the lateral walls which determine he configuration of each chamber. The thallus is fixed o the soil by numerous unicellular rhizoids, arising rom the midrib on the lower or ventral side. There are also *two longitudinal* rows of dark violet coloured ventral scales consisting of a single layer of cells springing from the thallus one on each side of the midrib.

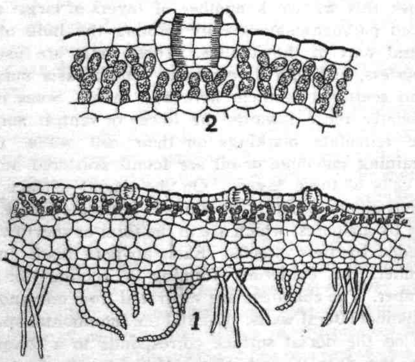


Fig. 265. –Sections of the thallus of *Marchantia polymorpha* showing the air chambers and the ventral portion bearing rhizoids and scales. 1, slightly and 2, highly magnified.

An examination of the vertical section of the thallus reveals its complicated anatomical structure and dorsi-ventral character. The rhizoids which fix the thallus to the soil are unicellular tubes and they are of two sorts. Some of them are simple tubes with smooth walls

while others have conical thickenings projecting into the cavity of the cell. The rhizoids are numerous and they form strands. Besides fixation, they absorb water and mineral salts to a small extent, although water is absorbed mostly by the plant body itself, as it is spread out and is in direct contact with the moist substratum.

The rhizoids and the scales spring from the outer most layer of the thallus on the lower side. This layer is the epidermal layer consisting of only one layer of cells. Above this we see a number of layers of large thin-walled parenchymatous cells forming the bulk of the ventral part of the thallus. These cells are usually colourless, although a few small chloroplasts may be found scattered in them here and there. Some cells, especially those towards the lower or ventral surface have reticulate markings on their cell walls. Cells containing mucilage or oil are found scattered amidst the cells of these layers. On the dorsal surface also there is an epidermal layer which is perforated here and there by air-pores, which are in the form of short canals bounded by tiers of cells. Each air-pore leads into a chamber, the epidermis forming a roofing for the chamber. The chambers are separated from one anothei by distinct lateral walls. Each of the rhomboidal spaces seen on the dorsal surface corresponds to a chamber From the floor of each of these air chambers severa short branched rows of small cells full of chloroplast arise. The development of the rows of chlorophyllou cells leads to an increase of the assimilating surface and these rows of cells are also placed in direct contac with the atmospheric air. These elaborate structura arrangements enable this Liverwort to carry on the wor of photosynthesis as vigorously and as efficiently as th higher land plants.

The thallus grows in length by the activity of a group of initial cells, formed from the apical cell at the growing point which is situated at the notched end of the thallus.

The gametophytes often multiply vegetatively by means of specialised bodies called **gemmae**, formed in cup-like out-growths arising frequently on the dorsal surface in the region of the midrib. These cup-like structures with toothed margins called gemma-cups contain a large number of gemmae. These are flat, oval-shaped, green bodies with short stalks. When mature a gemma gets detached from its stalk and then it develops into a thallus. As the number of gemmae formed in these cups are large, the Liverwort spreads to an enormous extent.

The sexual organs antheridia and archegonia are contained in the disc-like receptacles found at the ends of the erect special branches borne by the thallus. The branch bearing the antheridia is called an **antheridiophore** and the one with the archegonia, an **archegoniophore**. This Liverwort being dioecious the sexual organs are not found in the same plant, but occur in different plants. The stalks of the branches and the discs are only thalli that have become erect, the lower portion being contracted and the upper part expanded. The presence of rhizoids and scales in the grooves of the stalk and on the lower side of the disc shows their real nature. The internal structure of the disc is exactly similar to that of the thallus. The chambers and the air-pores are found on the upper surfaces of both the male and female receptacles.

The male receptacle is somewhat rounded with its free margin being slightly lobed. On the dorsal or upper side, a number of flask-shaped cavities are found in radiating furrows. All these cavities have small open-

ings on the upper surface and an antheridium is formed at the bottom of each of these cavities. The antheridia lying close to the centre of the disc are older than those at the periphery. An antheridium is a short-stalked oval body consisting of a wall of single layer of cells enclosing a large number of mother-cells of spermatozoids (or spermatozoids when mature).

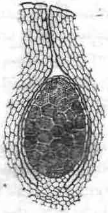


Fig. 266.—Section of a male receptacle of *Marchantia polymorpha* showing the antheridia. One antheridium is separately shown in section on a larger scale of magnification.

The female receptacle is a disc with nine or eleven radially disposed finger-like processes. The archegonia are found in two radial rows between the rays, these rows being surrounded by a sheath. The archegonia are formed at first on the upper surface of the disc, but later by growth and distortion they occupy the lower side. An archegonium is a short-stalked flask-shaped body consisting of a dilated lower portion or the **venter** and a very long **neck**. The wall of the venter is composed of a single layer of cells, and the neck is made up of six longitudinal rows of cells, closed at the apex when young. The oosphere and the ventral canal cell are in the venter and the canal of the neck

occupied by the neck-canal-cells. When the archegonium matures the ventral canal-cell and the neck-canal-cells change into mucilage, which escapes at the apex forcing apart the cells at the apex.

Fertilisation takes place only during the rain. It is only then that the spermatozoids escape and remain at the mouths of the cavities containing the antheridia. The liquid on the male discs get splashed to the female receptacles by rain drops. The spermatozoids that are thus carried to the surface of the female receptacles

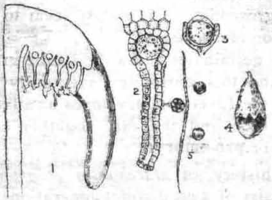


Fig. 257.—Section of a female receptacle of *Marchantia Polymorpha* showing archegonia and sporogonia. 1, vertical section of an archegoniophore; 2, an archegonium in section; 3 and 4, sporogonia; 5, spores and elaters.

are attracted towards the mouth of the archegonia by the mucilage extruded at the top of the neck. The spermatozoids are attracted by proteid substances contained in the mucilage. So these pass down the canal and one of them fuses with the oosphere. The zygote developes into an embryo which later on grows into the **sporogonium** or the asexual generation. In all the Liverworts the sporogonium remains attached to the sexual generation throughout its life. So it gets all the

materials needed for its growth and development from the gametophyte.

The sporogonium is a rounded body with a short stalk at first, and the stalk elongates with the growth of this body. In a receptacle when it is mature, a number of sporogonia are seen between the rays. The capsule of the sporogonium has a wall consisting of one layer of cells, except at the apex, where it consists of two layers of cells. The capsules burst open at the apex exposing the spores. Within the sporangium in addition to the spores, curiously elongated fibre-like cells having spiral thickenings are formed. These are called **elaters** and *they are hygroscopic. The elaters seem to be useful in* the dispersion of spores.

The spore germinates and a short tube grows out from the spore and this grows and eventually forms a disc from which the Liverwort developes as a lateral growth. The green tube and the disc together constitute the **protonema** or **pro-embryo**.

The life history of *Marchantia polymorpha* is thus seen to consist of two distinct generations, namely, the gametophyte and the sporophyte and these regularly alternate. The sporophyte gives rise to the gametophyte and the gametophyte produces the sporophyte.

Another Liverwort fairly common in the plains, namely, *Riccia sanguinea*, Kash., may be taken as another type of this group of plants. It grows on damp or marshy soils, its thallus forming small rosettes. The thallus consists of short, ribbon-shaped, dichotomously lobed or cleft branches radiating from the centre. The plants retain their rosette shape so long as they are isolated, but when they grow together the shape becomes irregular on account of the overlapping of the branches. The thallus is fixed to the soil by means

simple unicellular rhizoids springing from the nderside.

The structure of the thallus is very simple. The dorsal ide possesses air-chambers with openings towards the outside. But these openings are different from those of *Marchantia*. Although the air spaces are separated by short partition walls consisting of cells possessing chloroplasts, they are not so conspicuouly marked externally as in *Marchantia*. The ventral portion consists of uniform parenchyma. The rhizoids are unicellular and they arise from the lower epidermal cells.

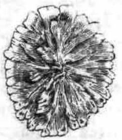


Fig. 268.—*Riccia sanguinea*, Kash., an entire plant.

This plant also is dioecious like *Marchantia*. The male plants are usually smaller than the female plants, and though mostly greeu, occasionally are of red colour. The female plants are always green in colour, somewhat larger than the male plant and more compact. The antheridia are somewhat ellipsoidal bodies found in the cavities formed on the dorsal surface of the thallus. The wall of the antheridium consists of a layer of single cells and the spermatozoids formed are all motile. The archegonia is of the type found in *Marchantia*, but smaller and more compact. After fertilisation the zygote developes into the sporogonium.

The sporogonium is of the simplest type. It is a spherical body without any stalk and occurs without any definite arrangement, as the archegonia occur irregularly in the thallus. Its wall consists of a single layer of cells and encloses a mass of tetrahedral spores. No elaters are formed in these sporocarps.

As in other Liverworts the spores escape by the rupture and disintegration of the venter and the surrounding cells of the thallus.

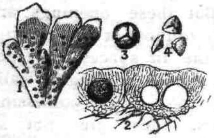


Fig. 269.—A portion of the thallus of the female plant of *Riccia sanguinea*. Kash. 1, thallus; 2, section of the thallus; 3, spore-mass; 4, spores.

Another Liverwort *Anthoceros* representing an isolated group of Hepaticae may also be examined. This genus is really one of a primitive order of Bryophyta. The gametophyte forms small green irregular patches on the ground amidst grass, soon after the rains. The thallus is simple, irregularly disc-shaped and is fixed to the soil by rhizoids.

The structure of the thallus is uniform, and large chloroplasts occur singly in the cells of the thallus. Clefts occur generally on the lower surface, and these lead to mucilage cavities, often invaded by Nostoc-colonies.

Plants of the species *Anthoceros laevis* are monoecious. The antheridia and archegonia are developed on the thallus of the same plant without any definite arrangement. The antheridia occur singly or in groups of two to four, entirely sunk in the thallus and in perfectly closed cavities. When these are mature the cells forming the covering get ruptured, and they open at their apices and discharge their spermatoziods. The archegonia also are found immersed in the tissue of the thallus and even when they are fully formed their necks do not project above the surface of the thallus.

After fertillisation the sporocarp is formed within the thallus and this emerges out rupturing the overlying membrane of cells by elongation. This membrane form

a sheath at the base of the sporogonium. When fully formed the sporogonium is a narrow elongated structure without a stalk and consists of a swollen foot and a long pod-shaped capsule. The capsule has a very slender columella, and the capsule splits gradually from above downwards and longitudinally into two valves. Along with the spores curiously-shaped multicellular elaters occur.

Fig. 270.—*Anthoceros laevis.*

The sporocarp has stomata and chloroplasts. So the sporophyte, represented by the sporocarp is capable of making its own food though it is dependent on the gametophyte for water and salts.

In all the Liverworts there is a distinct alternation of generations, the gametophyte invariably being the more conspicuous generation and the sporophyte always appearing as an appendage of the gametophyte.

MOSSES (MUSCI)

Mosses are more highly organised than Liverworts, especially in their sporophytes. The number of species amongst Mosses is very large and they are also widely distributed. They flourish in all sorts of places such as rocks, tree-trunks, logs, tops and sides of walls and on the soil. After monsoon rains almost everywhere patches of Mosses appear.

As types we may study species of *Funaria* and *Pogonatum.*

The Moss *Funaria* grows commonly in tufts on the surface of the ground, and it is sure to be found in many places. The conspicuous Moss-plant is the gametophyte

and it usually grows to a height of about half an inch. In it we can distinguish the stem and the leaves borne by the stem in a spiral manner. It must here be remarked that the leaves of Mosses cannot be homologous with the leaves of Angiosperms or Ferns, as in the latter the leaves belong to the sporophyte generation. At the base of the stem of the Moss-plant a large number of fine rhizoids are found fixing it to the soil. Branching of the shoot is very rare, and the lateral branches arise not from the axils of leaves, but from below them.

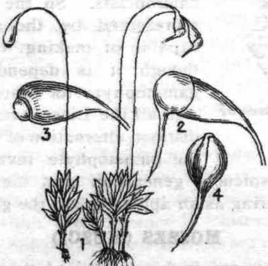


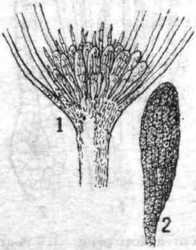
Fig. 271.—*Funaria hygrometrica.* 1, gametophytes bearing the sporophytes; 2, the theca with the calyptra; 3, capsule without the calyptra; 4, inner view of the calyptra.

Leaves of *Funaria* are simple, ovate, and sessile with entire margins. Every leaf consists of a single layer of cells, except at the midrib where there are more layers of cells. All the cells contain chloroplasts. Stomata are not found either on the leaves or on the stem.

The stem consists of a central core of elongated thin walled cells surrounded by a many-layered cortex. Chloroplasts are found in the peripheral layers of cell

ı the cortex, though not in the inner layers. The rowing point of the stem is terminated by a single pical cell, from which cells are derived by division.

The sexual organs, antheridia and archegonia, are eveloped on the same plant, and they occur in groups t the ends of shoots. The ends of stems bearing ntheridia become conspicuous, since the leaves near the ntheridia are close-set and spread out so as to form osette-like structures. These star-like structures consisting of leaves, antheridia and special hairs called **araphyses** are often termed "male flowers". Though rchegonia also are grouped at the free ends and covered y leaves, they are not conspicuous in any way. They re just like the leafy buds appearing at the free ends f shoots.



ig. 272.—Antheridia of a Moss. 1. A group of antheridia at the end of the stem; 2. A single antheridium highly magnified.

The antheridium is a club-shaped body just visible o the naked eye. It is really a sac with a stalk containing speramatozoids inside, still enclosed in cysts f ripe, or mother-cells of the spermatozoids if unripe.

The wall of the antheridium consists of one layer of cells containing chloroplasts when young, but these bodies turn yellow or red, at the maturity of the antheridium.

The archegonia are similar to those of the Liverworts, but with longer stalks and the venter with two layers of cells. The neck-canal cells become disorganised into mucilage and this mucilage is found at the free end of the neck of the archegonium. Usually this substance contains cane-sugar which is said to attract the spermatozoids. As in Liverworts, in Mosses also the spermatozoids are biciliated bodies.

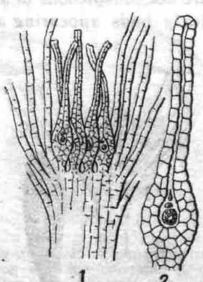


Fig. 273.—Archegonia of a Moss plant. 1. A group of archegonia 2, a single archegonium in longitudinal section.

After fertilisation the egg-cell grows into a sma elongated structure whose lower end or the **foot** becom sunk in the tissue of the gametophyte. Then with tl growth of this embryo the venter of the archegoniu also grows. Very soon the embryo begins to elonga into a long stalk-like body carrying with it the upp

portion of the archegonium which gets ruptured at the middle of the venter. Towards the free end of this rapidly growing embryo, there appears a capsule hidden by the upper torn portion of the archegonium, now termed **calyptra**.

A ripe sporogonium consists of a long stalk or the **seta** bearing the **capsule**, **urn** or the **sporesac** usually covered by the hood or calyptra. In *Funaria hygrometrica* the seta is bent at the top and the calyptra is oblique and tipped with a process. The capsule, urn or the **theca** is oblique and pyriform. The upper portion of the theca is differentiated into an oblique lid, and just below the lid or operculum there is a ring called **annulus** consisting of cuticularised epidermal cells. By the rupture of this ring the operculum is thrown off, and then at the top of the capsule we find a kind of membrane termed the **peristome** closing its mouth. The peristome

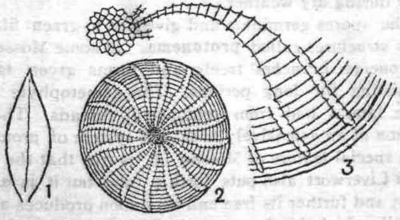


Fig. 274.—*Funaria hygrometrica.* 1, leaf; 2, peristome; 3, a portion of the peristome showing one tooth.

consists of two series of yellow triangular teeth, sixteen in each series. The basal portion of the capsule is solid consisting of parenchymatous cells and it is called the

apophysis. The epidermis covering the apophysis ha stomata and the cortex consists of cells containin chloroplasts.

The upper portion of the capsule is the part tha contains the spores. In the centre of the capsule lies core of sterile tissue constituting the **columella**. Sur rounding this columella there is the **spore-sac**, and it inner wall consisting of a single layer of cells lies nex to the columella, whilst its outer wall consisting of tw or three layers of cells is separated from the cortex c the capsule by intercellular spaces. The layers of cell lying outside the air space, which is traversed by strand of cells, form the wall of the capsule. The cells in th wall of the capsule also contain chloroplasts. So th sporocarp is able to do photosynthetic work, and so it i semi-parasitic on the gametophyte. Within the spore sac spores are formed and no elaters are developed. Th peristome teeth being hygroscopic, spores can escap *only during dry weather.*

The spores germinate and give rise to green filamen tous structures called **protonema**. In some Mosses th protonema branches freely and forms green tangle persisting for long periods. The gametophyte arise as a lateral bud from protonemal threads. The for mation of an extensively branched system of protonem is a special feature of Mosses. It is true that the spor of a Liverwort also puts forth a tube, but it is alway short and further its free end very soon produces a mas *of cells which develops into the Liverwort plant.*

Besides the formation of spores, Mosses propagat themselves very freely by vegetative reproduction. Thi kind of propagation seems to be more diversified an fruitful in Mosses than in any other portion o the vegetable kingdom. The protonema is capabl

of giving rise to the Moss-plant. Rhizoids produce very often protonema from which the normal plant arises, and sometimes rhizoids also give rise directly to the moss-plants. The gametophyte often forms gemmae and it is not unusual to have protonema developing from the leaves. Even parts of sporogonium are capable of producing protonema, which in its turn developes the plant. This great power of vegetative propagation is possessed even by *Funaria hygrometrica*. Rhizoid, stem, leaf and any part of the sporogonium can develop protonemata. Gemmae do not seem to occur in this species.

Now it must be obvious that the sporophyte generation is more highly developed in the Musci than in the Hepaticae. It is this sporophyte generation that becomes the most prominent generation in the groups higher than Bryophyta. The affinities of Bryophyta with other groups and the evolution of the sporophyte will be considered after dealing with Pteridophyta.

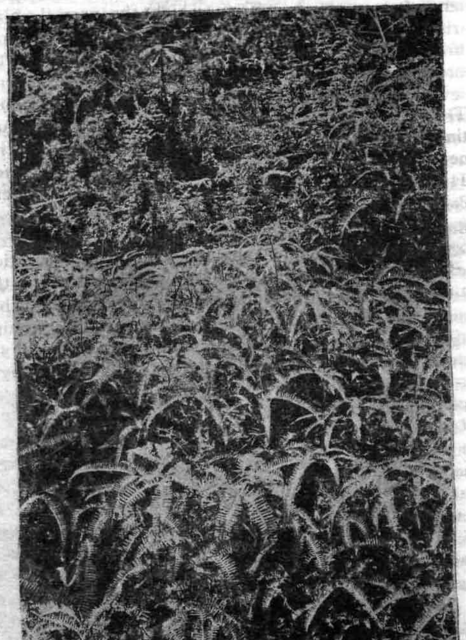


Fig.275.—*Gleichenia linearis*

CHAPTER XXI

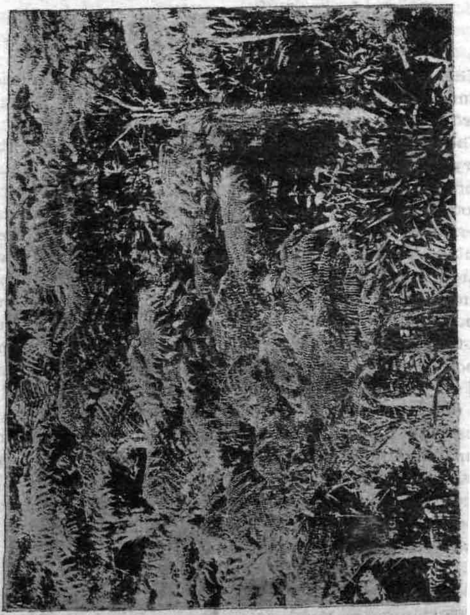
PTERIDOPHYTA

THE Vascular Cryptogams or the Pteridophyta consisting of Ferns, Water Ferns, Lycopodiums and Selaginellas represent the most highly developed Cryptogams. They occupy a position intermediate between the Bryophyta and the Spermatophyta. Since this group forms antheridia and archegonia like the Bryophytes, both these groups are included under a special class termed **Archegoniatae**. Like the Bryophytes the Vascular Cryptogams also have in their life cycle two alternating generations. But the green leafy plant amongst Pteridophyta is the asexual generation or the sporophyte, whilst the conspicuous plant in Bryophyta is the sexual generation, the gametophyte. Further the sporophyte is a very large plant in proportion to the size of the gametophyte in Vascular Cryptogams. Generally in this group the gametophyte is very small, inconspicuous and thalloid in form. Both the generations are capable of independent existence.

On account of the great diversity exhibited by plants of this group, we have to study as types certain species and we shall choose species of *Adiantum*, *Marsilia*, *Lycopodium* and *Selaginella*.

ADIANTUM

The common Maiden-hair-fern easily obtainable in gardens and conservatories is a typical example of Filices or true Ferns. We have a large number of species amongst true Ferns and they are widely distributed.



They generally flourish in shaded cool places, where water will become available in abundance at the time of fertilisation at least, since all Ferns are absolutely dependent upon water for fertilisation. In habit and size these plants present a great diversity. We have Ferns not above an inch or two with a very delicate moss-like habit, such as some species of *Trichomanes*. Some species of *Lygodium* are creepers. There are some Ferns which monopolise large areas and become the dominant species. The Bracken-Fern, *Pteris aquilina* is a most troublesome weed flourishing in the higher regions of Nilgiris and Pulney Hills. The Fern *Gleichienia linearis* (*G. dichotoma*) forms extensive thickets at the lower elevations in both the Western and the Eastern Ghats of South India, in sheltered moist gulleys (See Fig. 275). The greatest development is attained by Ferns in the Tropics. All moist shady situations in the Hills abound in Ferns. On the hills of South India in such situations we also find Tree-Ferns growing luxuriantly, especially in sheltered situations and these belong to the genera *Alsophila* and *Cyathea*. See Figs. (276 and 277).

The Maiden-hair-fern, *Adiantum capillus-veneris*, consists of an underground stem or rhizome growing horizontally. Leaves arise from its upper part and adventitious roots from its lower side. This Fern is a perennial plant. The rhizome is covered by thin scale-like structures called **ramenta**. Its elongation in the horizontal direction is chiefly due to the activity of its apical bud, which consists of the growing point and a rosette of young leaves all densely clothed with ramenta. Branching of the stem is neither frequent nor so profuse, as in the shoots of flowering plants. Occasionally the growing point becomes bifurcated and gives rise to two branches. Adventitious buds arise which develop in to

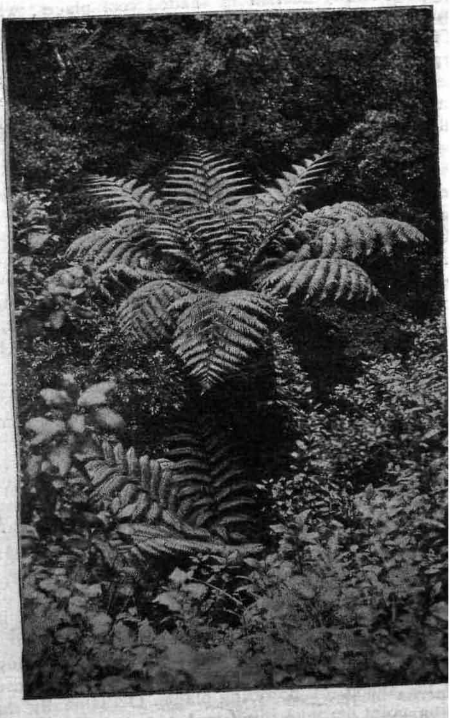


Fig. 277.—Tree-Fern.

branches. Axillary buds so characteristic of flowering plants, are unknown amongst Ferns.

The most striking feature of this Fern is the production of large, much divided leaves which, as in other Ferns, are always larger in proportion to the stem. When young the leaf is circinately folded and its growth is usually very slow, and the vigorous apical growth lasts a long time. Ordinarily only one leaf develops and matures into an expanded frond in one season. The main petiole and its branches are black and shining. The leaflets or pinnules are green, cuneiform with quite regular dichotomous venation.

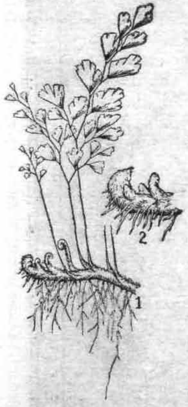


Fig. 278.—*Adiantum capillus-veneris*. 1, full plant; 2, the apical portion of the rhizome.

The *roots*, though adventitious, resemble those of the seed-plants in every way.

In Ferns the stem is essentially only the bearer of leaves and roots, and grows very slowly in length. It is woody and consists of tissues usually found in the stems of flowering-plants. In anatomical structure there is some resemblance between Ferns and flowering plants. The stem of *Adiantum* consists of a number of vascular strands embedded in the ground tissue which is parenchymatous. Very often strands of sclerenchyma also occur in the ground tissue, while hard stony or horny sheaths frequently form the surface of stem and leaf-stalk.

In the transverse section of the stem of *Adiantum* we see a number of vascular strands disposed in the form of a ring within a massive parenchymatous ground

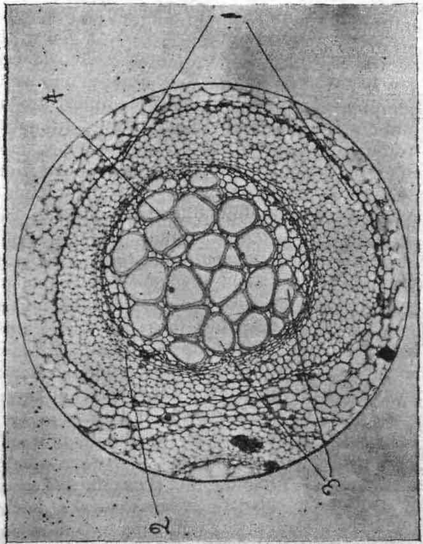


Fig. 279.—Transverse section of a vascular strand in the rhizome of a Fern. (Highly magnified.), 1, vascular strand; 2, phloem; 3, xylem; 4, middle lamella.

tissue. Each vascular strand consists of a central core of xylem surrounded by the phloem. The elements of xylem are mostly tracheids, the earlier ones being **spiral** and the later formed **scalariform**. The promi-

ıent elements of phloem are large sieve-tubes, with the sieve plates disposed laterally. Companion cells are not present. No cambium is formed. Outside the phloem lie the pericycle and the endodermis surrounding the vascular bundle.

The growing point of the stem has in its apex a single large cell, tetrahedral in shape, instead of a group of cells.

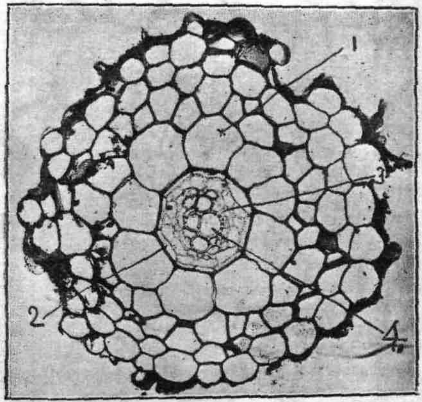


Fig. 280.—Transverse section of a root of *Adiantum*. (Magnified) 1, Endodermis; 2, pericycle; 3, phloem; 4, xylem.

The structure of the leaflets or pinnae resembles very much the structure of leaves of flowering plants growing in shady situations. The epidermal cells of the Fern leaf contain chloroplasts. The mesophyll cells of the

pinna constituting the chlorenchyma have air spaces amidst them, though the differentiation into palisade and spongy parenchyma is not very marked. The vascular

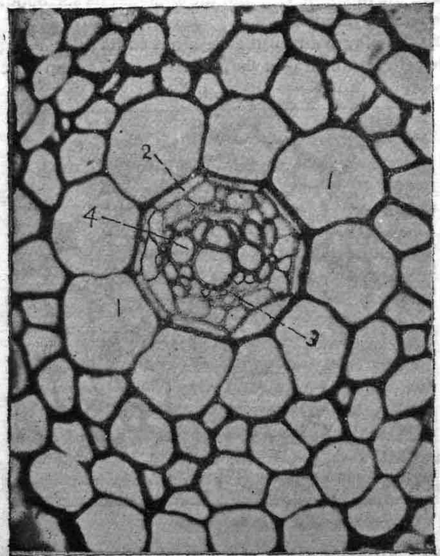


Fig. 281.—Transverse section of a root of *Adiantum* showing the stele 1, Endodermis; 2, Pericycle; 3, phloem; 4, xylem; Highl magnified.

strands traversing the leaflets are bicollateral in thei structure. Stomata are numerous in the lower epidermi

The structure of the root of *Adiantum* resembles very osely that of a diarch root of flowering plants. In this ot there is a superficial piliferous layer, a broad cortex ad a contracted stele. The stele is surrounded by an ndodermis. The pericycle also exists. There are two rotoxylem groups meeting in the centre and forming a late with phloem on both the sides. The cortex onsists of large parenchymatous cells.

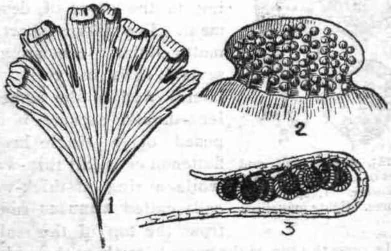


Fig. 282.—Leaflet and sori of *Adiantum capillus-veneris*. 1, a pinnule; 2, a flap turned up to show the sori; 3, section through the flap showing the sporangia.

The Fern plant being the sporophyte it must produce spores, The spores are formed within the spore-cases or **sporangia** as they are called, and on the lower surface of the leaflets sporangia are produced in large numbers. In *Adiantum* in mature fronds, the edges of some of the pinnules are folded down. At first when

the pinnae are young these folds are not conspicuous, but become prominent later on as the pinnae get older. If these flaps are turned up brown spots called **sori** become visible on the underside. Each sorus is a group of sporangia in different stages of development. The sori are connected with the ends of veins.

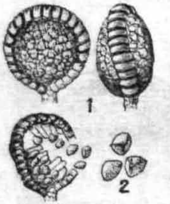


Fig. 283.—Sporangia and spores of *Adiantum capillus-veneris*. 1, sporangia; 2, spores. Highly magnified.

A sporangium consists of a short stalk and a sporesac or capsule containing spores or spore mother cells, according to the stage of development. The stalk is short and multicellular consisting of several rows of cells. The lateral wall of the somewhat lens-shaped capsule is composed of a single layer of flattened cells, all thin-walled, while a ring of thick-walled cells called **annulus** runs up from the top of the stalk on one side, over the top of the capsule to about the middle of the other side. In each of the cells of the annulus the inner and the radial walls are thickened, whilst the outer and the side walls remain thin. Between the end of the annulus and the top of the stalk a number of thin-walled cells are found. This part is called the **stomium**, and this being the weakest point dehiscence occurs here.

The sporangia when ripe contain spores inside and dehiscence is caused by the movements of annulus brought about by its rupture at the stomium. So long as the sporangium is young all its cells contain water and hence all of them will be turgid. But with the ripening of the sporangium there will be a gradual diminution of

water, and this must necessarily affect the annulus. In consequence of the escape of water the thin walls of the cells forming the annulus begin to shrink, and at the sametime the thickened radial walls will tend to come close together. As the loss of water affects all the cells of the annulus, it tends to shrink as a whole and this must necessarily cause the rupture of the sporangium at the stomium. As the lateral portions of the capsule consist of thin-walled cells, the splitting will extend from the weakest point to its sides.

On the occurrence of this rupture the annulus loses its tension and becomes almost straight. Along with it the upper portion of the capsule with spores will also be carried. Gradually the cells of the annulus get filled with air and finally the annulus returns to its original position with a quick jerk. This very rapid snapping back to its former position throws out the spores to a considerable distance.

If sections of pinnules across the flaps are examined, sporangia in various stages of development may be seen, and they would be found connected with the prolongations of the veins. A sporangium is formed from a single superficial cell of the pinna by successive segmentations. By repeated divisions the stalk and the capsule are formed. The capsule consists of a wall enclosing sporogenous tissue, and this sporogenous tissue in the early stages consists of one or two layers of flat cells lying next to the wall of the capsule and a number of cells in the centre which later become rounded and develop into spore-mother-cells. The inner layer of cells found lying close to the sporangial wall forms the **tapetum**. The tapetal cells get disorganised and serve as nutritive cells for the spore-mother-cells. Gradually the nutritive cells are absorbed, and the

spore-sac will ultimately consist of the wall of the capsule and the spore-mother-cells within. Each spore-mother-cell divides into four spores. During the cell-division leading to the formation of spores, reduction division of the nuclei occurs. The development of spore-mother-cells into spores by reduction division is exactly similar to the formation of pollen-grains in the pollen-sacs of anthers.

The leaves of Adiantum bearing the sporangia are exactly like sterile leaves. The former are often called **sporophylls** and in some Vascular Cryptogams, the two kinds of leaves, namely sporophylls and vegetative leaves, are very well differentiated.

The spores of this Fern are very small and light. A spore is really a single cell covered by two distinct membranes, namely, an **endospore** or an internal layer of cellulose and an **exospore** or a cutinised external layer. The spores are produced in enormous numbers and they are all of only one kind. Hence this Fern-plant is **homosporous**. *As a matter of fact, all true* Ferns are homosporous. The spores of Ferns being very small and light they float in the atmosphere like dust. When spores are sown on moist earth, or on brick, or pieces of tile standing in water, and kept in moist air they germinate and form small green, thin bodies called **prothalli**. A prothallus when fully formed is somewhat heart-shaped with a broad deep depression in the front. It becomes fixed to the soil or substratum by numerous rhizoids. As a rule the prothallus is only one cell thick, except in the middle which is somewhat thicker and consists of more than one layer of cells. This thickened part is called the cushion. All the cells *are provided with chloroplasts.*

The prothallus is able to lead an independent

istence, although it is small and never grows larger an half an inch. It is the sexual generation or the *ımetophyte. For its development and for the fulfilment* its part in the life cycle of the Fern, a moist habitat is necessity. The sexual organs antheridia and archeonia are developed on the lower surface of the rothallus.

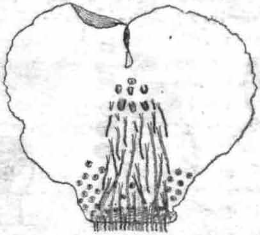


Fig. 284.—Prothallus of a Fern.

The **antheridia** are usually found towards the base of the prothallus amidst the *rhizoids*. They are small outgrowths consisting of a mass of cells enclosed by a wall of one layer of dome-shaped cells. The central mass of cells develops into spermatozoid mother-cells or **spermatocytes.** When the antheridium is mature its wall bursts at the top setting free the spermatocytes. For the proper development of the antheridia, and their rupture external water is necessary. The escape of spermatocytes and the liberation of the spermatozoids from them is possible only when fluid water is available. The spermatozoids have many cilia and they can move about only in water. The antheridium is formed from a single superficial cell.

The archegonia are found somewhat close to the depression in front of the prothallus, and a little to the front of the antheridia. Each archegonium consists of a short neck bent over and away from the growing point

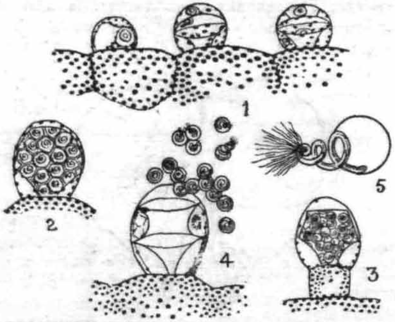


Fig. 285.—Antheridia and spermatozoids of a Fern. 1, antheridia and cells of the prothallus; 2 and 3, antheridia enclosing spermatocytes; 4, an antheridium burst open and setting free the spermatocytes; 5, spermatozoid. (Modified from Kny's diagram.)

and a flask-shaped portion or venter immersed in the body of the prothallus. It is the neck alone that protrudes beyond the surface of the thallus. The neck has a canal leading into the venter in which the egg-cell lies. The archegonium also arises from a single superficial cell of the thallus. Like the antheridia, archegonia also need external water for their opening at the free end of their necks to allow the spermatozoids to enter.

The spermatozoids are attracted to the mouth of the archegonia by the mallic acid in the mucilaginous substance present in the neck-canal. They are caught in the viscid substance lying at the broad mouth of the neck

f the archegonium. Working its way through the eck-canal, the spermatozoid reaches the oosphere or gg-cell and fuses with it. The single cell resulting from

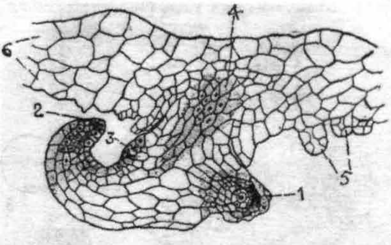


Fig. 286.—Section of a young sporophyte growing out from the prothallus of a Fern, highly magnified. 1, root-apex; 2, leaf-tip; 3, growing point of the stem; 4, foot; 5, archegonia; 6, body of the prothallus.

the fusion of the egg-cell and the sperm-cell begins to divide repeatedly and finally develops into the ordinary Fern plant.

The zygote or the oospore divides into eight cells and the upper four by further division give rise to the axis and the leaves, and from the four lower cells **the foot** and the root develop. In the seedling illustrated here the leaf, the foot, the future axis, and the root are, clearly seen. (See figs. 286 and 287.)

In *Adiantum* and all true Ferns the sporangia consist of only one layer of cells with transverse or longitudinal dehiscence. A distinct annulus is present, though its position in the sporangium may vary. These Ferns which embrace the largest number of species are included under the class **Leptosporangiate** Ferns. There are

some Ferns such as *Marattia*, *Angiopteris*, *Ophioglossum* and *Botrychium* in which the sporangia have walls formed of a number of layers of cells. There is no

Fig. 287.—Section of an young sporophyte growing out from the prothallus of a Fern highly magnified. 1, root-tip; 2, leaf-tip; 3, growing point of stem; 4, foot; 5, archegonium.

annulus, and the sporangia dehisce by longitudinal slits. The sporangia are developed on the lower surface of the leaves in the first two genera, whilst in the third and

the fourth, they are borne by the leaves as special segments quite distinct from the green flat leaf segments. In *Ophioglossum* the sporangia are borne by a simple

Fig. 288. *Botrychium*. An Eusporangiate Fern. Note the branched segment bearing sporangia.

cylindrical spike, but in *Botrychium* the part bearing the sporangia is a pinnately branched spike. (See fig. 288.) These genera constitute the class **Eusporangiate** Ferns.

The life-history of the Fern plant is most interesting. It has two distinct phases in its life-cycle, namely, the prothallus or the **gametophyte** and the Fern plant or the **sporophyte**. These two generations regularly

alternate and, as already stated, alternation of generations is a typical feature of Ferns. Compared with the Bryophytes, the sporophytes of Ferns are very much advanced, and they lead an independent existence and are not dependent on the gametophyte. The adaptation, already foreshadowed in Bryophyta to a life on land, is perfected in Ferns in their sporophytes. The sterile tissue has increased to enable the plant to adjust itself to its surroundings much better, and the sporogenous tissue is external. From this arrangement the plant is able to produce enormous amount of spores and compete successfully in the struggle for existence. The gametophyte, on the other hand, is small and inconspicuous and retains a thalloid structure throughout its life, although in Bryophytes this is the generation that is better developed and conspicuous. It is adapted for life in moist situations only and the object of its existence, namely, fertilisation is possible only in the presence of fluid external water. The gametophyte is the haploid generation as reduction division occurs during the formation of spores, and the sporophyte is the diploid generation since the nuclei get a double set of chromosomes as the result of fusion of sexual cells. The zygote is the beginning of the sporophyte and the spore of the gametophyte.

MARSILIA OR WATER-FERN

The marsh-weed *Marsilia minuta* is a Fern though it does not appear to be so at first sight. The plant is easily recognised by its creeping stem and long stalked leaves with four spreading cuneate leaflets. The weed is a sporophyte generation adapted for living either as a marsh-plant or an aquatic plant.

The creeping stem is slender, cylindrical and branches

freely. As in *Adiantum* leaves arise from the dorsal side, and the ventral side gives off adventitious roots. A transverse section of the stem shows a compact central stele, surrounded by a fairly large cortex. Being

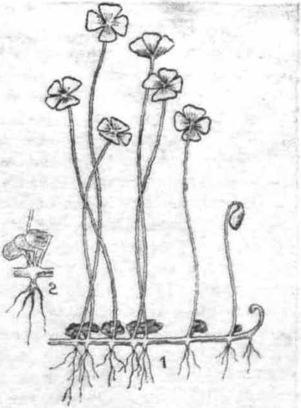


Fig. 289.—*Marsilia minuta*, L. 1, Full plant; 2, sporocarps.

aquatic in habit numerous air cavities occur in the peripheral portion of the cortex. These cavities are separated from one another by radial trabeculae. In young stems diaphragms stretched across the air spaces are also seen. Externally there are two layers of cells overlying the air cavities. The inner portion of the cortex is compact and consists of several layers of cells. In this inner portion of the cortex two or three layers of cells lying close to the air cavities become thickened as the stem

gets older. The vascular bundles form a cylinder in the centre of the stele and the hollow centre of this cylinder is filled with parenchymatous cells. There are two

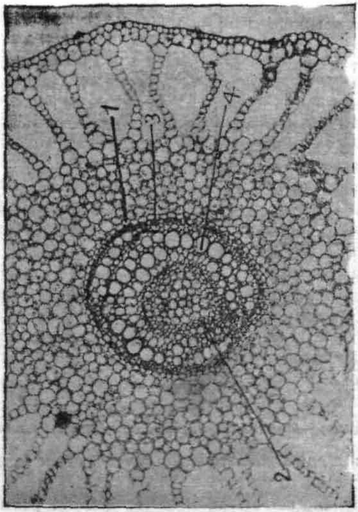


Fig. 290.—Transverse section of the stem of *Marsilia coromandelica* as seen under low power. 1, outer endodermis; 2, inner endodermis; 3, phloem; 4, xylem.

distinct layers of endodermis, one forming the external boundary of the stele and the other surrounding the central core of the fundamental tissue lying within

the vascular cylinder. The elements composing the xylem and phloem and the arrangement of these two kinds of tissues within the stele are similar to what obtains in the homosporous Ferns. In other words, the vascular bundles are of the concentric type. The xylem is surrounded by the phloem.

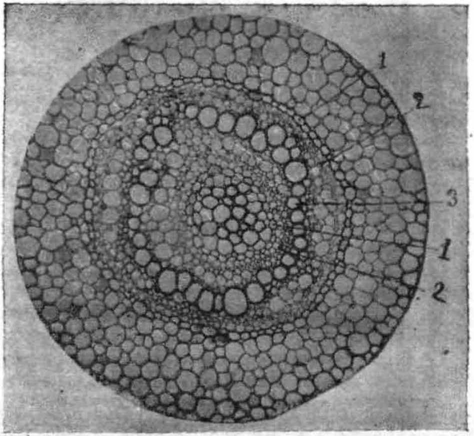


Fig. 291.—Transverse section of the stem of *Marsilia coromandelica* showing the stele as seen under high power. 1, endodermis; 2, phloem; 3, xylem.

Leaves are circinately folded when young as in other Ferns. The leaf has a long petiole bearing two pairs of lobed leaflets cuneate in shape. The margins of the leaflets are irregularly toothed. Of the four leaflets two

are inserted a bit higher than the opposite pair. The venation of the leaflets is of the forked or dichotomous type.

The structure of the petiole is more or less similar to that of the stem. The cortex possesses air spaces like

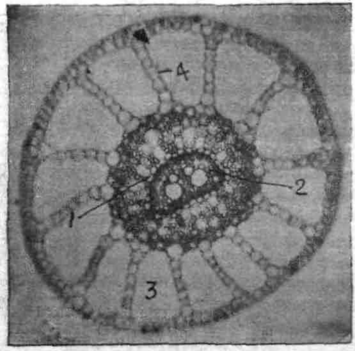


Fig. 292.—Transverse section of the petiole of *Marsilia* under low power. 1, endodermis; 2, xylem; 3, air cavity; 4, trabeculae.

the stem, but there is only one endodermis. The vascular bundle is smaller and the xylem is surrounded by the phloem.

Being a *sporophyte* this plant produces spores of two kinds namely small spores called **microspores** and very large spores termed the **megaspores**. Both the kinds of spores are formed within the sporangia, the microspores in **microsporangia** and megaspores in **megasporangia**, which are collected together in **sori**.

Each sorus consists of a few megasporangia and a number of microsporangia. The sori do not appear on the lower side of the leaflets as in other Ferns but are found within special receptacles called sporocarps

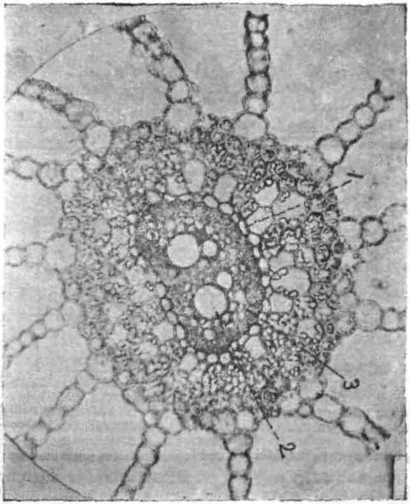


Fig. 293.—Transverse section of the petiole of *Marsilia* under high power. 1, endodermis; 2, xylem; 3, phloem.

on short leaf-stalks in the place of leaflets. The sporocarp is a bean-shaped body with a very hard rind, within which the sori are disposed in two rows on its sides. All

the sori are attached to a ring running round the sporocarp. When a sporocarp is placed in water after scraping the hard shell in one or two places, it splits and from within, the ring, which now becomes mucilaginous, comes out bearing on it a large number of sori.

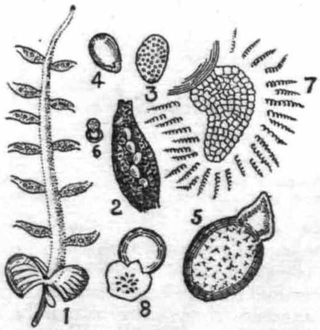


Fig. 294.—Sporocarp, sporangia and spores of *Marsilia minuta*. 1, Sporocarp that has germinated. Note the gelatinous stalk bearing the sporangia, now extended. 2, a compartment containing sporangia; 3, a microsporangium; 4, a megasporangium; 5 and 7, germinated magaspores with prothallus and spermatozoids swarming close to the prothallus; 6 and 8, microspores germinating.

The sporocarps are hardy bodies retaining their vitality for a very long time. The hard shell is impervious to water and forms an efficient protective covering for the sporangia. Sporocarps taken from herbarium sheets collected half a century ago and those preserved in 50 per cent spirit resume their activity as soon as they are placed in water.

As a consequence of heterospory, the development of the gametophyte is also affected. Since there are two kinds of spores, two distinct gametophytes are formed, and they are very much reduced and do not emerge from the spores. The microspore germinates and a number

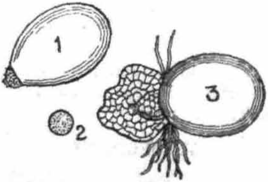


Fig. 295.—Spores of *Marsilia minuta*. 1, megaspore; 2, microspore; 3, megaspore after fertilisation with the embryo formed in it.

of spermatozoids come out of it as the result of germination. The male gametophyte consists of a single cell and a single antheridium, formed inside the microspore. The spermatozoid is a coiled body with a large number of cilia attached to the lower coils. The megaspore germinates and forms a small female gametophyte with a single archegonium. As the megaspore possesses an external layer which becomes mucilaginous when placed in water, on germination a thick mucilaginous layer is formed and at the top of the spore a deep depression is formed, and it is at the base of this pit that the prothallium protrudes. It is into this mucilaginous funnel shaped pit that the spermatozoids get into in large numbers to fertilise the egg-cell or ovum. The greater portion of the spore except the lenticular part at its apex is a large nutritive cell full of starch and oil globules. These are used as food-material by the developing prothallus and the embryo is formed in it after fertilisation.

The most interesting feature of *Marsilia* is the heterospory and the aggregation of the two kinds of sporangia in a hard sporocarp which keep their vitality for a very long time.

Besides the species *Marsilia minuta,* which is of very wide distribution there is another one *M. coromandelica* also of common occurrence. This differs from the former in having larger leaflets without any marginal teeth and the sporocarps also are larger. In both the species a number of sporocarps appear on short petioles in the months from February to May.

LYCOPODIUM

Several species of *Lycopodium* are found growing on the hills in moist situations. Many of them are terrestrial plants, although a few of them are pendulous epiphytes. One of the commonest species found in this Presidency is *Lycopodium cernuum* and this may be taken as typical of the class.

The shoot-system of this plant, which represents the sporophyte generation, consists of prostrate stems running for considerable distances, either on the surface amidst rotting leaves and humus, or beneath the soil, and numerous secondary branches growing erect some of which terminating in sporiferous spikes or cones. The primary as well as the secondary branches are all clothed with small narrow oval-shaped leaves. The stem branches in a dichotomous manner, and branches are never axillary.

Roots spring from the prostrate stems and they also branch dichotomously after penetrating the soil.

The growing point of the stem consists of a number of cells without any separation into distinct embryonic layers. The epidermal cells of the stem contain chloro-

plasts, and stomata also occur in the epidermis of the leaves and stems. A transverse section of the stem shows a central stele surrounded by a fairly broad cortex. A few layers of cells of the cortex lying close

Fig. 296.—*Lycopodium cernuum* in its natural habitat.

to the stele become thick-walled due to lignification. The single layer of cells of the endodermis and a pericyle of two layers of cells are distinctly seen. The xylem in the stele is in the form of flat plates, effecting unions in various ways one with the other. The elements of

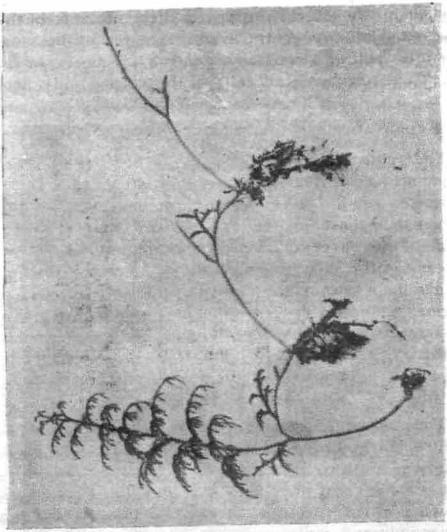


Fig. 297.—*Lycopodium cernuum.* Entire plant

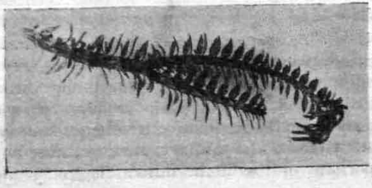


Fig. 298.—An epiphytic pendulous species of *Lycopodium.*

the xylem are spiral, pitted and scalariform tracheids. The phloem surrounds the xylem.

Roots arise from the peripheral layers of the stele and come out piercing the cortex. Their internal structure is after the type of the stem. The root-tip consisting of a group of cells is covered by a root-cap.

The club shaped-bodies called cones and found terminating the final branches consist of an axis with close-set small leaves, which are, however, slightly larger than those on the axis below. In the axils of each of the leaves of a cone a sporangium is developed, but not in the axils of leaves in other parts of the stem. Since the leaves of the cone have sporangia they are termed sporophylls. In this plant the leaves are thus differentiated into sporophylls or fertile leaves and ordinary sterile leaves. There are a few species of *Lycopodi m* in which all the leaves produce sporangia in their axils without any differentiation.

The sporangia produce only one kind of spores and hence this plant is **homosporous**. The sporangium dehisces into two valves, and sets free the spores which are so small and abundant that they form a very fine powder which is of some commercial importance. This Lycopodium-powder is used in coating pills and in pyrotechnics. The spore has a reticulated outer coat the exosporium and an inner cellulose coat the endosporium.

The prothallia developing from the spores present a remarkable variation in *Lycopodium*. The prothallus of *L. cernuum* is a cylindrical cushion-like mass of tissue poor in chlorophyll and attached to the soil by rhizoids. Green aerial thalloid lobes are formed in the upper portion of the prothallus. The antheridia and

archegonia appear amidst these lobes. All prothallia of Lycopodiums are perennial and have mycorhiza or fungal hyphae in their peripheral tissue. The spermatozoids are biciliated.

The spores of Lycopods germinate very tardily, some of them do so only after six or seven years. Prothallia also seem to require a very long time to develope. In some species the prothallus is said to become sexually mature only after twelve to fifteen years.

We thus see that Lycopodiums are distinguished by certain special features. The leaves, which are so conspicuous in Ferns, are in this group very small in size in proportion to the stem. The branching of the stem and root is dichotomous. The gametophyte generation or the prothallium is perennial in all species, and in some it takes over twelve years to form the sexual organs on it. The spores also germinate only after five or six or more years. The sporangia are produced singly in the axils of leaves.

SELAGINELLA

Many species of *Selaginella* occur in the plains on the west coast, and on the hills they form a most attractive feature of the forest vegetation. They are grown in gardens on account of their beauty and for their decorative effect. They have usually creeping profusely-forked stems, and often form moss-like beds of vegetation. Some are small, others large and climbing and a few are even xerophilous. Selaginellas resemble the Lycopodiums in their habit.

For purposes of study *Selaginella plumosa*, a fairly common species in South India, or *Selaginella inequalifolia*, largely cultivated as an ornamental plant may be

chosen. The shoot-system of *Selaginella plumosa* consists of stems branching very freely in an apparently dichotomous manner, and all the branches lie more or less in the same plane. Axillary branches do not occur and they develop from lateral buds arising near the apex of the stem. Since the lateral bud and the apical bud of the stem grow equally well, branching appears to be dichotomous.

Fig. 299.—*Selaginella plumosa.* Entire plant with rhizophores.

The slender stems and branches are clothed with small leaves, which form four rows. Two rows on the upper or dorsal side of the branches consist of small leaves, while the two rows on the ventral side springing from the sides of the branches are somewhat larger.

From below the stem where it forks springs a naked greenish specialised branch named **rhizophore**, and this after penetrating the soil develops roots at its free end. These slender specialised branches arise exogenously and resemble the root in their internal structure. Since rhizophores occasionally develop into ordinary shoots, *they must be considered as special branches of the stem.*

At the apex of the stem at the growing point a single cell is found in some species, and in others two or three cells, all dividing, occupy the apical end. The stem is traversed by one or two vascular bundles which are surrounded, each by a circle of air spaces across which the endodermal cells are stretched as trabecular cells. The vascular bundles are *of the concentric type*, and the elements found are similar to those existing in the vascular strands of Ferns.

Leaves are all simple with entire margin. At the base of each leaf on the upper surface a small membranous out-growth called the **ligule** is developed. The cells of the leaf including the epidermal cells usually contain *one or two large chloroplasts.* There is *only* one vein running through the middle, and it is of the concentric type in its structure and arrangement of xylem and phloem.

As in *Lycopodium*, sporangia arise from the axils of sporophylls which usually form cones at the ends of branches, at certain seasons of the year. All the leaves *forming the cone bear sporangia singly in their axils.* This *Selaginella* plant being heterosporous, two kinds of sporangia, namely, microsporangia and megasporangia are developed. The former are formed in large numbers in the axils of the upper sporophylls, whilst the latter are confined to the axils of a few sporophylls at the basal portion of the cone. Generally only four megaspores

are formed, and the microspores are many in a sporangium.

The sporangial wall consists of two layers of cells, and the stalk is a short one.

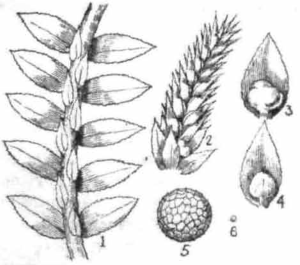


Fig. 300.—*Selaginella plumosa*. 1, a portion of a branch; 2, a cone bearing sporangia in the axils of sporophylls; 3, megasporangium; 4, microsporangium; 5, megaspore; 6, microspore.

The microspores are all very small bodies. On germination the spore forms inside it a small prothallial cell and some peripheral cells enclosing a few cells in the centre which develop into spermatocytes later on. In some of the species of *Selaginella* in which the development of the gametophyte has been observed during the germination of the spores, the peripheral cells get absorbed and the mother cells alone remain. Spermatozoids with two cilia escape by the rupture of the wall of the spore. Compared with the microspores the megaspores are very large. On one side of this spore three radiating ridges are seen and it is here that it bursts. A large amount of reserve material, chiefly in the form of oil is

found inside these spores. The megaspores seem to begin their development in some species within the sporangia, and before escaping from them. By repeated cell division the interior of the spore becomes filled with cells, and these represent the prothallium. The wall of the spore bursts at the place where the three radiating lines are seen and the prothallium protrudes through this opening. Archegonia are formed in the portion of the prothallus protruding through the slit at the top.

Fertilisation is practically similar to that of Ferns. The embryo grows and developes into the sporophyte plant.

In all the Pteridophytes the sporophyte generation is independent and shows progressive development. We find in the parts of these plants differentiation of tissues into different kinds. Amongst leaves, most of them are sterile foliage leaves and a few are spore-bearing leaves or sporophylls. In some plants the sporophylls do not materially differ from the sterile leaves, whilst in others they look slightly different and are aggregated together at the extremeties of branches as cones. Some are homosporous and others heterosporous. The prothallium is an independent sexual generation or the gametophyte, resulting from the germination of the spores and bears the sexual organs. In the case of homosporous plants the prothallia are quite independent plants and in heterosporous forms the prothallia develop within the spores and never emerge from them.

Selaginella may be considered to be a form leading from Pteridophyta to seed-plants or Spermatophyta. The microspores and megaspores of this plant are homologous respectively with pollen-grains and embryo-sacs. In Spermatophyta the pollen-grains alone get detached from the sporophyte. In *Selaginella*, on the

her hand, megaspores as well as microspores are shed :fore germination and are not borne by the sporophyte. One feature that characterises Archegoniatae is the gular occurrence of alternation of generations. The rcumstance that the sporophyte is dependent on the ametophyte amongst the Bryophata led many to the iew that both the generations are homologous. In ther words, it was thought that both had a common rigin and are equivalent. From recent cytological esearches we now know that the sporophyte is a diploid generation and that the gametophyte is haploid. In the ight of this information it would be preposterous to iold the view that the sporophyte is homologous with the gametophyte.

This phenomenon of alternation, though not known in most forms of Thallophyta, seems to be a general feature in the case of the seaweeds *Dictyota* and *Polysiphonia*. In both these Algae two distinct generations, alike in their vegetative parts, but one bearing tetraspores and another having only sexual organs occur in regular alternation. The plants bearing tetraspores appear to be diploid and those producing the sexual cells haploid. Reduction division takes place during the formation of the spores and doubling of the chromosomes is brought about by the fusion of the sexual cells. On account of the aquatic habit there is no difference between the two generations of plants in their vegetative parts.

If we consider the salient features of these two generations as presented by the various species of the Archegoniatae, we notice a steady progressive development of the neutral or sporophyte generation, coupled with the absence of progress in the gametophytic generation. Even amongst Bryophytes we find a

SPERMATOPHYTA

THE Spermatophyta occupy the highest position amongst the types of vegetation. These merely continue the advance already begun in the sporophytes of Pteridophyta. The alternation of generations so characteristic of the Archegoniatae is still maintained by the Spermatophyta.

One distinctive feature of this group of plants is the production of seed as the result of fertilisation. After the formation of the embryo the seed gets separated from its parent plant, the sporophyte. The seed is merely the megasporangium modified to a certain extent. The seed contains the megaspore with the prothallium and the embryo.

The predominance of seed-plants in the Flora of the present day is a clear proof of the success achieved by the Spermatophytes in the struggle for existence. This extraordinary success is due to the further progress attained by the sporophyte over the Selaginellas. Like *Selaginella* the seed-plants also produce two kinds of spores, namely, microspores or pollen-grains and megaspores or ovules. But the megaspore never leaves the sporophyte parent plant. By this means protection and conditions necessary for proper nutrition to the egg-cell and the embryo are secured.

The Spermatophyta are divided into the two classes:—

(1) **Gymnosperms** in which the ovule is naked, not being enclosed by a carpellary leaf and (2) **Angiosperms** in which the ovule has a carpellary protection.

CHAPTER XXII

GYMNOSPERMS

GYMNOSPERMS occupy an intermediate position between Angiosperms and Vascular Cryptogams. These plants do not figure so much in the Flora of the present day. They form but an insignificant portion of the Flora, in spite of their predominance in former times. As a matter of fact, the living representatives of this group appear rather isolated and distinct from one another. This is so as these are survivals of a large class that existed in earlier periods. In South India the only genera of this group that occur in a wild state are *Cycas*, *Podocarpus* and *Gnetum*. Of these three *Podocarpus* is of very local distribution,occurring only in Tinnevelly and Travancore Hills. In Northern India the forests abound in several species of Gymnosperms such as Pines, Firs, Yews, Spruces, Junipers and Cedars. Some species of *Pinus*, *Cupressus* and *Araucaria* are grown on the hills as ornamental shrubs.

As examples of Gymnosperms we may study the plants *Cycas cincinalis*, *Pinus longifolia* and *Pinus excelsa*. The first represents the order Cycadeae and the other two belong to the order Coniferae.

CYCADEAE

The tree *Cycas circinalis*, L., occurs in many gardens as an ornamental plant. It is also met with in a wild state in hilly parts of South India. But it is not abundant anywhere. The tree bears a superficial resemblance to the palms and is like the Tree-Ferns in many respects.

Its stem is erect, usually unbranched, thick with its exterior covered by the leaf-bases and scales.

This tree bears at its summit a crown of leaves which persists for a year or two, and is then replaced periodically by successive crowns of leaves. There are two kinds of leaves, namely, the foliage leaves and the scale-leaves. As soon as a rosette of foliage leaves is formed and the leaves are fully expanded, the terminal bud of the stem is visible and it is enveloped in scale-leaves. Within this bud and under the protection of these scale-leaves the next set of foliage leaves develops rather slowly.

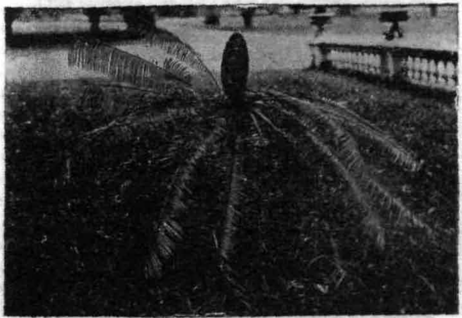


Fig. 301.—Tree of *Cycas circinalis* with a male cone.

Thus we see that at the summit of the tree one set of foliage leaves is separated from the succeeding set by a succession of scale-leaves. The group of foliage leaves, enveloped by the scale-leaves in the terminal bud, takes a year or two to develop and unfold itself as the

next rosette of leaves. The scale-leaves are very much smaller than the foliage leaves, but are more in number.

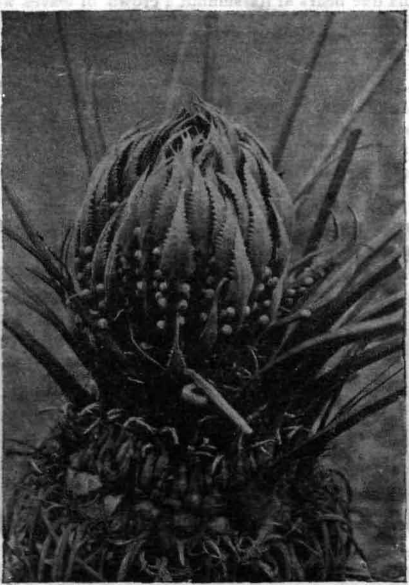


Fig. 302.—Female cone of *Cycas circinalis*, L.

The foliage leaves are long, varying in length from four to eight feet. They are compound, simply pinnate with a strong midrib and a leaf-stalk of about a foot

and a half, which bears short distant spines to almost near the base of the blade. The pinnae are long, linear, one-nerved, thick, green, shining and about quarter of an inch broad. In young leaves the leaflets are folded circinately as in Ferns.

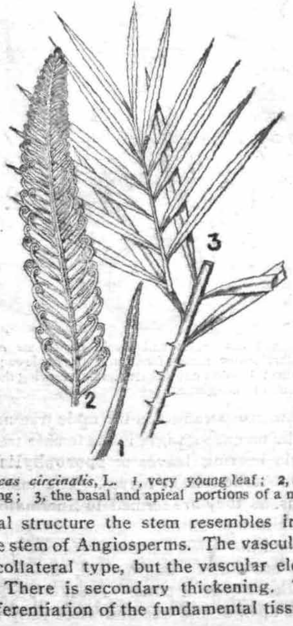


Fig. 303.—*Cycas circinalis*, L. 1, very young leaf; 2, a young leaf just unfolding; 3, the basal and apical portions of a mature leaf.

In internal structure the stem resembles in essential respects the stem of Angiosperms. The vascular bundles are of the collateral type, but the vascular elements are tracheids. There is secondary thickening. There is a distinct differentiation of the fundamental tissue into the

the pollen-chamber. The structure of the pollen-grain betrays that it is really a microspore. There is a single vegetative cell which is all that is left of the prothallium. Another cell, lying close to this prothallus-cell and called the spermatogenous cell, gives rise to the male gametes or spermatozoids. The pollen-grain germinates and forms a

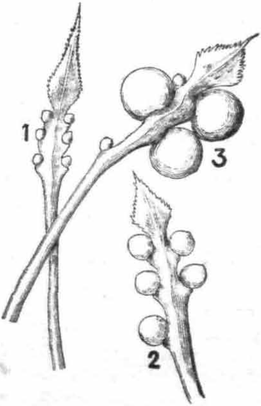


Fig. 305.—Megasporophylls of *Cycas circinalis.* 1, young megasporophyll; 2 and 3, older megasporophylls.

tube which absorbs food from the remnants of the nucellus. In addition to these absorbing tubes, other tubes larger than these arise from the pollen-grains, and these tubes carry the generative cell further down into the pollen-chamber. The generative cell passes down to the extremity of the tube and becomes divided into two spermatozoids. The spermatozoids are interesting

bodies. They bear a large number of cilia and so they are capable of movement. (See fig. 306). As soon as the pollen-tube reaches the archegonium it empties its watery contents. The *spermatozoids* get into the archegonium by moving through this water. Afterwards fertilisation is effected and the embryo is formed.

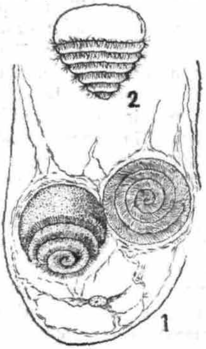


Fig. 306.—Sperm-cells of *Cycas revoluta*. 1, pollen-tube, with two sperm-cells; 2, side view of a spermatozoid or sperm-cell. (After Ikeno and Coulter.)

Cycads are the simplest and the lowest type of all the living Spermatophyta. It is the only plant which produces naked seeds without developing a cone or flower. While it possesses certain characteristics peculiar to the seed-plants, in many respects it resembles the Pteridophyta. The formation of multiciliate spermatozoids, the development of the formation of the gametophyte within the megaspore, the circinate vernation of the leaflets and the presence of sporophylls show the relationship of the *Cycas* to the heterosporous Vascular Cryptogams. The development of the seed and the gametophyte remaining attached to the sporophyte, being enclosed in the megaspore until the [formation of the embryo, are forward steps towards Spermatophytes. The presence of the pollen-chamber below the micropyle is a special character of the Gymnosperms.

CONIFERAE.

The two Pines, *Pinus longifolia*, Roxb., and *Pinus excelsa*, Wall., both belonging to the order Coniferae, are grown as ornamental trees in parks in the hill stations in South India. They are lofty trees somewhat symmetrical and with a characteristic pyramidal shape. The main stem is quite straight and it can be traced from the ground to the top of the tree. This is possible because the apical growing point usually remains intact and it is capable of indefinite growth. Numerous lateral branches are formed and each of them retains its apical bud which grows indefinitely. The lower branches are longer than the upper, and they get gradually shorter and shorter towards the top of the tree, thus giving the shoot as a whole the pyramidal shape.

In Pines we have two kinds of branches, namely, long branches that are completely covered by brown scale-like leaves and spur-shoots or dwarf branches growing out from the axils of the brown membranous scale-leaves. As the number of axillary buds capable of growth is very much limited compared with Angiosperms, the dwarf shoots are numerous. Each spur-shoot has at its apex a cluster of needle-shaped green leaves. In *Pinus longifolia* the cluster consists of three leaves and in *Pinus excelsa* the dwarf shoot bears five to eight leaves in each cluster.

Leaves are of two kinds, namely, the scale leaves borne by the long branches and the foliage leaves found at the ends of spur shoots. The base of the cluster of leaves is always sheathed by thin membranous scales of the terminal bud of the dwarf branch. Pine leaves persist on the tree for several years. Therefore, this tree is never bare of leaves, although each year some of the

der leaves drop off. With the fall of the cluster of aves, the spur-shoots dry up.

As regards the reproductive bodies, pollen-grains ıd ovules, both are borne by the tree as in *Cycas*

Fig. 307.—*Pinus excelsa*, Wall. 1, branch with leaves and male cones; 2, a male cone; 3 and 4, staminal scales; 5, pollen-grains.

by sporophylls. But the Pines are monoecious. Consequently both the megasphorophylls and microsporophylls are found on the same tree, though they are separately borne as male and female cones. The male or staminate cones occur in clusters. Each male cone is a cylindrical body, about half an inch long,

consisting of a central axil bearing antheriferous scales in spirals. A scale bears on its lower side two anthers or sporangia.

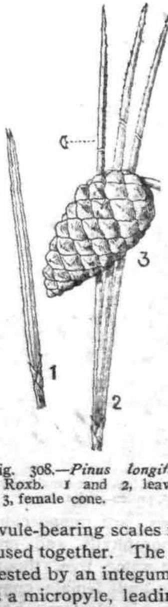


Fig. 308.—*Pinus longifolia* Roxb. 1 and 2, leaves; 3, female cone.

The female cones usually occur singly and not usually in clusters. Like the male sporophylls, the megasporophylls also are borne spirally by a central axis, the whole structure forming a cone. Each megasporophyll bears two ovules on the lower side.

The *pollen-grains* are rather peculiar bodies. They are provided with two air-sacs one on each side of a grain. In a fully mature pollen-grain, we can make out four cells distinctly. They are two prothallial cells, a tube cell and the mother-cell of the antheridium. The two prothallial cells are not always clear, sometimes disorganised remnants only being visible.

The megasporophyll has two ovules. Each of these ovule-bearing scales is believed to be two sporophylls fused together. The ovule consists of the nucellus invested by an integument. At the apex of the ovule there is a micropyle, leading to a cavity below, the pollen-chamber. Within the nucellus endosperm is formed and a remnant of the nucellus persists at the top near the

pollen-chamber. The endosperm corresponds to the gametophyte or prothallium formed in the megaspore of *Selaginella*.

Pollen is produced in abundance. The air-sacs facilitate the floating of the pollen-grains in large numbers in the air. Consequently some of them get into the female cones and reach the pollen-chambers at the base of the micropyle. When the female cones are ready for pollination the scales gape open. In this case pollination is really the lodging of the pollen-grains in the pollen-chamber. After pollination the scales close up without leaving any passage.

The pollen-grain germinates in the pollen-chamber, and forms a tube at first with which it absorbs food material from the remnants of the nucellus. Later on another large tube is formed which goes deeper into the pollen-chamber. At this stage there are only two cells in the grain, namely, the mother-cell of the antheridium and the tube-cell. The tube-cell descends to the end of the pollen-tube, and the other cell, the mother-cell divides into a stalk-cell and a generative cell. While these changes are going on, there will be formed in the prothallial tissue or the endosperm four or five archegonia.The pollen-tube reaches the archegonium, and by bursting, pours in its contents and the generative cell now divided into two germ cells. One of the germ-cells, now reduced to a nucleus, fuses with the egg-cell in the archegonium. After this fusion the embryo is formed.

Soon after the lodging of the pollen-grains in the pollen-chamber, the micropyle closes by the growth of the integument in thickness, and the scales begin to grow and close up. In some species of Pines the scales secrete a resinous substance, which forms an effective barrier

for water. The cones increase in size very much after fertilisation. The process of pollen germination and fertilisation are of longer duration in Pines than in other seed-plants. The formation of the seed and the ripening of the cones are also prolonged for nearly a year.

Amongst Gymnosperms the Pines and other species of Conifers are higher forms and they approach the Angiosperms in several respects. In the anatomical structure of stems and roots, there is a great resemblance between Angiosperms and Conifers, at any rate in all essential features. The only difference appears to be that the elements of xylem are all tracheids and not trachea.

CHAPTER XXIII

ANGIOSPERMS

THE seed-plants with ovules enclosed in ovaries are the Angiosperms and they form the most highly organised group. These plants are dominant over other kinds of plants, and are of endless diversity in size, structure and mode of life. We have Angiosperms such as Wolffia that are so small as to appear as a mere green speck side by side with gigantic trees. To get an insight into the forms of plants some kind of grouping of them is necessary. From the time of Linnaeus several systems of classification were adopted and the system of Linnaeus is the earliest.

The main object of classification is to set forth, as far as possible, the relationship existing between plants owing to their descent from common ancestors. It must be clearly understood that no system of classification can be expected to be perfect and final, as our knowledge of the various aspects of plant life is still imperfect. As our knowledge increases, the scheme of classification will become more and more a true reflection of the true relationship of plants.

It is customary to divide the Angiosperms into **Dicotyledons** and **Monocotyledons**. Both these classes have distinct characteristics, justifying their separation. The monocotyledons were once thought to be more primitive than the Dicotyledons. From recent researches we learn that the Monocotyledons are derived from some forms now included under the order Polycarpicae. This order includes the Families Ranunculaceae, Anonaceae,

Magnoliaceae, Nymphaeaceae, Menispermaceae, and others. There is a considerable amount of agreement in floral construction, anatomical structure and in morphological characters between Monocotyledons and the Polycarpicae.

The Dicotyledons, as the name implies, have two seed-leaves or cotyledons in their seeds. Leaves are reticulately veined. Flowers are pentamerous and pentacyclic. A well marked tap-root exists and the stem grows in thickness in these plants.

Monocotyledons, on the other hand, have a single cotyledon in their seeds. Leaves are parallel veined and have sheathing leaf bases. Flowers are trimerous. A tap-root does not exist. There is no secondary thickening of the stem.

These two classes are further subdivided into Sub-Classes, Series and Families.

For purposes of classification, all individual plants of a kind that are usually raised from the seeds of the same kind of plant of a previous generation are all alike, and so all these plants are said to be of one **species**. The species are grouped into higher classes called **genera**, and the group of a higher rank than the **genus** is the Family. As an illustration we shall consider certain definite plants and their classification.

The common okra or Lady's Finger is called *Hibiscus esculentus*,L. All okra plants wherever they may be are grown from seeds of a previous generation. The offspring resemble the parents in many respects and so we recognise them as forming a species. Similarly we have the species *Hibiscus micranthus*, *Hibiscus rosa-sinensis* and *Hibiscus vitifolius*. On comparison we find that all these species possess certain characters in common and they are the following:—The calyx is

gamosepalous with a whorl of bracts at its base; there are five petals twisted and adherent at the base to the staminal column; the stamens form a monadelphous tube with unilocular anthers, enclosing a superior ovary and a filiform style which ends in five stigmatiferous branches. These are the characters of a genus and the name of the genus is *Hibiscus.*

If we compare the various species of *Hibiscus* with the plants Portia tree and *Abutilon indicum*, we can trace certain similarities in some respects. In all these plants the calyx is monosepalous, petals contorted and adnate with the staminal tube at the base; the stamens are monadelphous forming a tube and the anthers are unilocular. These characters are enough to constitute the Family Malvaceae. We may set forth these facts in a tabular form and show the limits of the Species, Genus and the Family.

Plants with gamopetalous calyx, free contorted petals adherent at the base with the staminal tube, and anthers unilocular ... *Malvaceae.*

Plants of this Family may be divided into Genera and Species as detailed below by taking the examples mentioned above.

Style not branched at the free end ... *Thespesia.*
Style branched at the free end.
  Epicalyx not present—
    Style branches and carpels more than twenty ... *Abutilon.*
  Epicalyx present—
    Style branches and carpels five. *Hibiscus.*

Species of the genus Hibiscus

Flowers small.
  Petals white—
    Fruits small round; seeds cottony. *H. micranthus.*

Flowers large.
  Petals red –
    Fruit not developed ... *H. rosa-sinensis.*
  Petals yellow—
   Fruit short.
    Fruit naked and angled ... *H. vitifolius.*
    Fruit covered with close-set bristles ... *H. cannabinus.*
   Fruit long.
    Calyx spathaceous ... *H. esculentus.*

There are two Natural Systems of classification in vogue at the present time. They are (1) Bentham and Hooker's system and (2) Engler's system. The former is adopted in all British and Indian Floras, whilst on the continent of Europe and in America the latter with modifications is in use. Of the two systems, Engler's system of classification is considered superior to the other system, as the relationships of plants are better brought out by this one.

Families dealt with in this book grouped according to Bentham and Hooker's system.

DICOTYLEDONS

Polypetalae

1. *Thalamiflorae.*—

Anonaceae, Nymphaeaceae, Cruciferae, Capparideae, Polygalaceae, Portulacaceae, Malvaceae, Sterculiaceae, and Tiliaceae.

2. *Disciflorae*—
   Rutaceae, Meliaceae, Rhamneae, and Sapindaceae.
3. *Calyciflorae*—
   Leguminosae, Combretaceae, Myrtaceae, Cucurbitaceae, Aizoaceae, and Umbelliferae.

Gamopetalae

1. *Inferae*—
   Rubiaceae, and Compositae.
2. *Heteromerae*—
   Sapotaceae.
3. *Bicarpellatae.*—

Apocynaceae, Asclepiadeae, Boragineae, Convolvulaceae, Solanaceae, Scrophularineae, Acanthaceae, and Labiatae.

Incompletae

1. *Curvembryae*
   Amarantaceae.
2. *Unisexuales*
   Euphorbiaceae, and Urticaceae.

MONOCOTYLEDONS

1. *Microspermae*—Orchideae
2. *Epigynae*—Scitamineae, and Amaryllideae
3. *Coronarieae*—Liliaceae, and Commelinaceae
4. *Calycinae*—Palmae
5. *Nudiflorae*—Aroideae
6. *Glumaceae*—Cyperaceae, and Gramineae

Families dealt with in this book grouped according to the system of Engler.

DICOTYLEDONS

I. Archichlamydeae

Urticales—Urticaceae
Centrospermae—Amarantaceae, Aizoaceae Portulacaceae.
Rannales—Nymphaeaceae, Anonaceae.
Rhoeadales—Cruciferae, Capparideae.
Rosales—Leguminosae.
Geraniales—Rutaceae, Meliaceae, Polygalaceae, Euphorbiaceae.
Sapindales—Sapindaceae.
Rhamnales—Rhamnaceae.
Malvales—Malvaceae, Sterculiaceae, Tiliaceae.
Myrtiflorae—Combretaceae, Myrtaceae.
Umbelliflorae—Umbelliferae.

II Sympetalae

Ebenales—Sapotaceae.
Contortae—Apocynaceae, Asclepiadeae.
Tubiflorae—Convolvulaceae, Boragineae, Labiatae, Solanaceae, Scrophularineae, Acanthaceae.
Rubiales—Rubiaceae.
Cucurbitales—Cucurbitaceae.
Companulatar—Compositae.

MONOCOTYLEDONS

Glumiflorae—Gramineae, Cyperaceae.
Principes—Palmae.
Spathiflorae—Araceae.
Farinosae—Commelinaceae.
Liliflorae—Liliaceae, Amaryllideae.
Scitamineae—Scitamineae.
Microspermae—Orchideae.

CHAPTER XXIV

DESCRIPTION OF FAMILIES

DICOTYLEDONS

Anonaceae

Types :—*Polyalthia longifolia, Benth.*
Anona squamosa, L.

Polyalthia longifolia is a small handsome evergreen tree with straight trunk which branches freely. Leaves are shining, bifarious, lanceolate with undulate margins, exstipulate, shortly petiolate and studded with pellucid glands. Flowers green, in short fascicles or umbels, arising from old branches. Sepals small, three, valvate and triangular. Petals six in two series of three each, valvate, flat and spreading from the base, thin, ovate and elongated at the tip. Stamens indefinite, spirally arranged on a prominent convex receptacle, hypogynous and cuneate; anther-lobes extrorse, concealed by the dilated end of the connective. Ovary of free carpels with one or two ovules in each. Fruit a number of free one-seeded berries.

Anona squamosa is a small tree with a bifariously arranged leaves which are simple, exstipulate, alternate, short-stalked, oblong, entire and glaucous beneath. Flowers are greenish-white, solitary or fascicled. Sepals are three, small, membranous and valvate. Petals are three, valvate, thick and fleshy, and concave at base. Stamens are indefinite, hypogynous, spirally packed on the receptacle; anther-lobes hidden by the dilated tip of the connective. Ovary is superior many-carpelled, syncarpous. Fruit is a many-seeded globose berry.

Characters of the Family:—Members of this Family are mostly trees and a few scandent shrubs. Leaves are exstipulate, entire and bifarious. Flowers are bisexual,

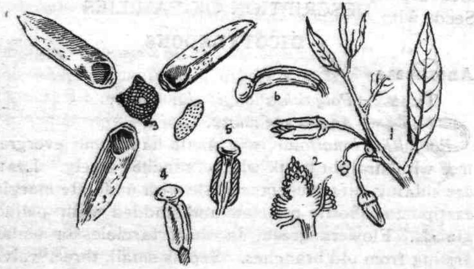


Fig. 309.—*Anona squamosa*. 1, a branch with leaves and flowers; 2, section of the receptacle with stamens and pistils; 3, parts of the flower; 4, 5 and 6, different views of the stamens.

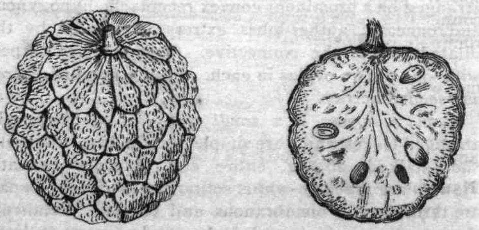


Fig. 310.—*Anona squamosa*. 1, entire fruit; 2, fruit cut through.

solitary, fascicled or umbelled. Sepals are small thin and valvate. Petals are six in two series of three each, or three. Stamens are indefinite, hypogynous, closely

and spirally packed on the torus, with short filaments; anther-lobes linear, usually crested by the dilated end of the prolonged connective. Ovary is superior of indefinite carpels, usually free. Fruit apocarpous and fleshy. Seeds with ruminate endosperm.

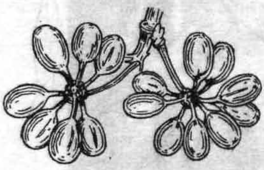


Fig. 311.—Apocarpous fruits of *Polyalthia longifolia.*

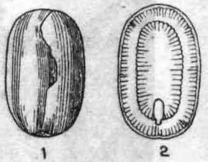


Fig. 312.—Seeds of *Polyalthia longifolia.* 1, entire seed; 2, seed cut longitudinally to show the ruminated endosperm.

The most striking features of the Family are the spirally arranged stamens with the dilated tips of the connectives, apocarpous gynaeceum and seeds with ruminated endosperm.

This Family is a tropical one. The common genera met with in South India are *Uvaria, Artabotrys, Miliusa, Saccopetalum* and *Alphonsea*.

The fruits of *Anona squamosa* are full of sweet pulp and edible.

Nymphaeaceae

Types:—*Nymphaea pubescens*, Willd.
Nelumbium speciosum, L.

Nymphaea pubescens has got a creeping underground stem, with long-stalked, large leaves, floating on the surface of water. Leaves are rotund, with a deep sinus at the base, peltate. The lower surface of the leaf is

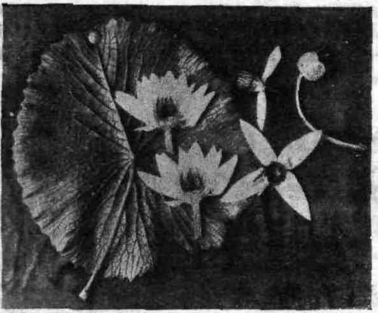


Fig. 313.—*Nymphaea pubescens*, Willd. Leaf and floral parts.

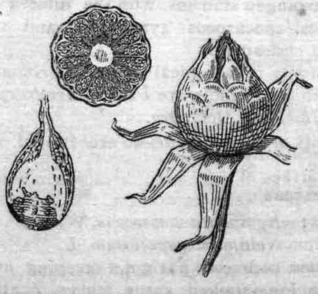


Fig. 314.—*Nymphaea pubescens*, Willd. Entire fruit, trans
section of fruit and a seed

reddish, with very prominent spongy viens and the upper surface green, smooth and cannot be wetted. Flowers are solitary on long scapes and floating. Sepals are four, oblong. Petals are twelve or more, unequal, oblong, white or red. Stamens are many with flat filaments.

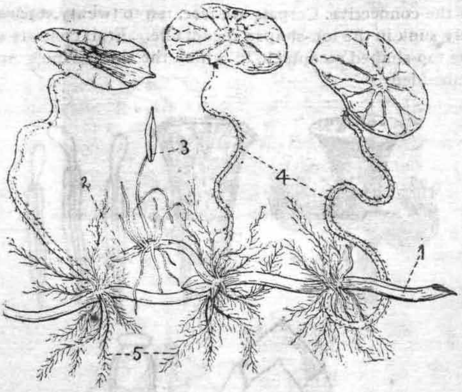


Fig. 315.—A plant of *Nelumbium speciosum*, Willd. 1, Rhizome; 2, yonng bud; 3, involute young leaf; 4, petiole; 5, roots.

Both the petals and the stamens are spirally attached to the outer surface of the ovary. Ovary is of many carpels fused with the fleshy receptacle. The fruit is a soft berry with many cavities lined with seeds, which are globular, tubercled, and enclosed by a sac-like aril. Seeds contain both endosperm and perisperm.

Nelumbium speciosum is the well-known Lotus plant, flourishing in ponds and tanks. It has a creeping shoot-system, rooting at the nodes. Leaves are long-stalked

raised above the level of the water and cup-shaped in the middle. Flowers are large, solitary, on long peduncles. Sepals are four or five. Petals fifteen to twenty or more, unequal, white or red, deciduous. Stamens are numerous hypogynous, with a club-shaped appendage to the top of the connective. Carpels are free, ten to twenty, separately sunk in the top-shaped receptacle. Fruit consists of the top-shaped receptacle in which the ripe carpels are imbedded.

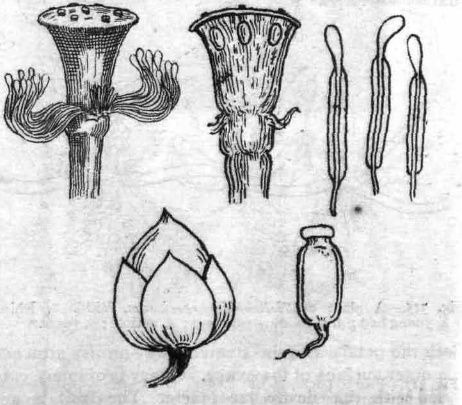


Fig. 316.—A flower bud, stamens, ovary and receptacles o *Nelumbium.*

Characters of the Family:—Aquatics with latex in th vegetative parts. Leaves are large floating on water, o raised above it. Flowers are large on long stalks. Sepal

are indefinite with flat filaments, with or without appendage to the connective. Ovary of many carpels either fused with the receptacle, or free and immersed in it. Fruit is fleshy or spongy. Seeds with both perisperm and endosperm, or only with endosperm.

Cruciferae

Type:—*Raphanus sativus*, L.

Raphanus sativus is the Radish, cultivated for the sake of its tuberous roots. It is a biennial, with sessile, pinnately lobed leaves. Inflorescence terminal, corymbose

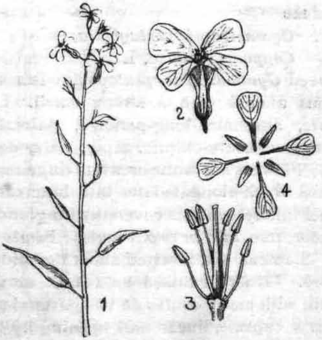


Fig. 317.—Floral parts of the Radish (*Raphanus*) 1, inflorescence; 2, a flower; 3, tetradynamous stamens and the pistil; 4, sepals and petals.

when young and racemose when in fruit. Flowers are white or pinkish white and ebracteate. Sepals are green, narrow, four, in whorls of two, the inner whorl bulging at the base on account of the two glands on the receptacle. Petals are four, free, clawed at the base and disposed

cross-wise. (Stamens are tetradynamous with two glands in the axils of the shorter stamens.) Ovary is superior, two-carpelled with parietal placentation. Fruit is a silique. Seeds brownish. Cruciferae are easily recognised by the tetradynamous stamens and clawed cruciform petals.)

This Family is not so well represented in the tropics. The only genera occurring in South India are, *Nasturtium*, *Cardamine* and *Capsella*. Other plants of this Family such as the Indian Mustard, Turnip, Cauliflower, Cabbage, Knol-khol are cultivated.

Capparideae

Types :—*Gynandropsis pentaphylla*, DC.
Capparis sepiaria, L.

The weed *Gynandropsis pentaphylla* is a tall, hairy, herbaceous annual with a strong smell. Leaves are exstipulate, alternate, long-petioled, palmately-lobed; leaflets five, obovate-elliptic, acute, hairy on both the surfaces. Flowers are white or white tinged with purple, in corymbs which elongate later into bracteate racemes. The whole inflorescence is covered with glandular hairs. Sepals four, free, and in two whorls. Petals four, long-clawed. Stamens six, inserted about the middle on the gynophore. Ovary is raised on a stalk or gynophore, one-celled, with many ovules on two parietal placentas.

Fruit is a capsule, linear and opening by two valves. Seed reniform with a curved embryo.

Capparis sepiaria is a straggling shrub, with wiry branches forming bushes in hedges and scrubby places. Leaves oblong or oblong-lanceolate, with stipular thorns. Flowers small in umbels. Sepals four in two whorls. Petals four, white. Stamens indefinite, inserted on the torus at the base of the gynophore, and not on the gynophore. Ovary on the gynophore with many ovules on

parietal placentation. Fruits berried, black. Seed with bent embryo and kidney-shaped.

Over fifteen species of *Capparis* are found in South India and some of them have large handsome flowers.

Several species of this Family occur in South India and they are of the genera, *Cleome* and *Cadaba.*

Cleome has indefinite stamens but there is no gynophore. *Cleome chelidonii*, L. f., with its pink flowers occurs as a weed in clay and black cotton soil. *C. viscosa*, L., grows as a weed all over the plains. It has yellow flowers and the plant is viscously hairy.

The genus *Cadaba* has only four stamens on the gynophore, and the striking feature is the presence of a tubular disk, projecting from the centre of the flower. Seeds are enveloped in red arils.

Crataeva religiosa, Forst., is a small tree with broad corymbs of white flowers having stamens, with purple filaments when the tree is bare of leaves.

Characters of the Family:—Herbs or shrubs, rarely trees. Leaves with stipular thorns, simple or compound. Flowers umbelled with four sepals, in two series, and four petals. Stamens four, six or many, attached to the gynophore or not. Ovary one-celled with or without the gynophore. Fruit a capsule or berry with seeds on parietal placentas.

Polygalaceae :—The common weed of the black cotton soil and of heavy soils *Polygala erioptera*, DC., Var. *Vahliana* is typical of this Family. This plant is an annual with softly hairy alternate leaves, almost sessile and oblong or oblong-obovate. Flowers pinkish in extra-axillary racemes. Sepals five, unequal and the two inner large and petaloid. Petals three, united at the base with the staminal sheath, the lower petal crested at the tip and boat-shaped. Stamens eight, monadelphous and

forming a sheath split on one side. Fruit a two-celled loculicidal capsule, with a seed in each cell. Seeds hairy, with a waxy three-lobed appendage and endosperm.

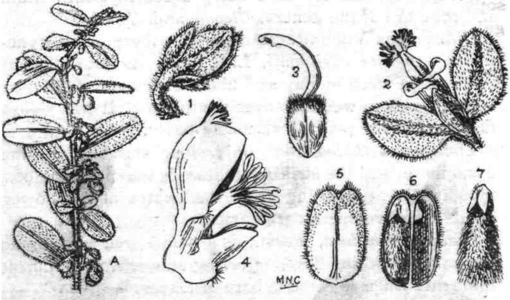


Fig. 318.—*Polygala erioptera.* DC. Var. *Vahliana.* A, a branch, 1, a flower bud ; 2, a flower ; 3, the gynaeceum ; 4, the petals and stamens; 5, a fruit ; 6, fruit cut longitudinally ; 7, a seed.

Portulacaceae:—These are succulent herbs, with fleshy leaves having scarious stipules. Flowers bisexual. Sepals two, joined below and the free part deciduous. Petals four or five, fugacious, yellow or pink. Stamens definite, or indefinite, with fine filaments. Ovary half inferior, unilocular with three-to eight-fid style ; ovules many from the base, or on a central column. Fruit usually a capsule opening transversely by means of a lid. Seeds blackish and with endosperm. *Portulaca oleracea*, L., and P. *quadrifida* L., occurring as common weeds may be examined as types.

Malvaceae

Types :—*Pavonia procumbens, Boiss.*
Hibiscus rosa-sinensis, L.

Pavonia procumbens is a small shrub growing in clayey soils. Leaves alternate, stipulate, broadly ovate, irregularly dentate, and long-petioled. Flowers solitary, axillary, with five triangular bracteoles, united at the base. Calyx of five triangular lobes. Petals five,

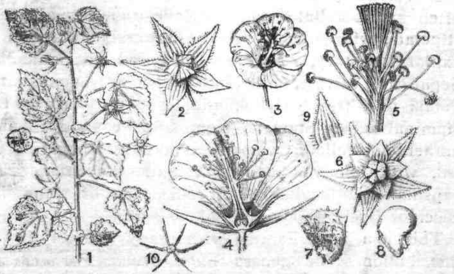


Fig. 319.—*Pavonia procumbens.* 1, a branch; 2, a flower bud; 3, a flower; 4, longitudinal section of a flower; 5, staminal column and style branches; 6, fruit and calyx with epicalyx; 7, a coccus; 8, a seed.

yellow, connate at the base and adherent to the staminal tube. Stamens united into a tube, and anthers of several groups at intervals. Ovary five-celled with one ovule in each. Fruit a schizocarp, breaking into five, muricate, glabrous cocci.

Hibiscus rosa-sinensis, L., is the common garden shoe-flower plant. A freely branching shrub producing large showy axillary solitary flowers. Leave simple, short-stalked, ovate, dentate; stipules linear. Flowers large

with a jointed peduncle and with six or more linear gree bracteoles. Calyx with five triangular lobes. Petal free, large, red, contorted, adnate at base to the stamina tube. Stamens united into a tube, antheriferous onl at the upper half; anthers one-celled. Ovary superio five-celled with many ovules on an axile placenta style long and branched into five branches, at the fre end.

Characters of the Family:—Herbs, shrubs and trees often with stellate hairs. Leaves simple, alternate stipulate, with palmate veins. Flowers hermaphrodite axillary, solitary, sometimes clustered or paniculate Sepals five, valvate, united into a lobed or truncate calyx Petals five, free, twisted, adnate to the base of th staminal tube. Stamens monadellphous and tubular anthers one-celled. Ovary three- to five- or many-carpel led, with numerous ovules on axile placentas. Frui capsular and loculicidal, or schizocarp breaking int cocci, or rarely woody and indehiscent.

This is a large Family with many species of wid distribution. The genera *Sida, Urena, Pavonia* an *Hibiscus* are of general occurrence. In *Sida* and *Abutilo* the number of carpels and style branches are the sam in number; but in *Urena* and *Pavonia* style branche are twice as many as the carpels.

Some species of economic importance are largel cultivated. They are the Cotton plants, *Gossypiu herbaceum*, L., G. *barbadense* and G. *hirsutum*, *Hibiscu cannabinus*, L., *H. esculentus*, L., and H. *sabdariffa*, L The trees *Eriodendron anfractuosum*, DC., and *Bomba malabaricum*, DC., yield Silk cotton.

Sterculiaceae

Plants of this Family resemble those of Malvacea

nd Tiliaceae. Inflorescence in axillary cymes, regular ıni- or bi-sexual. Calyx gamosepalous, five-lobed. Petals ve, twisted. Stamens free, or united. Ovary five-celled. uit capsular.

As types *Melochia corchorifolia*, L., and *Waltheria dica*, L., may be examined. *Helictres Isora*, L., is a mmon shrub of low jungles with large irregular crimn flowers. The petals are irregular, stamens tubular d the ovary is stalked. The fruit consists of five ıear follicles, more or less spirally twisted.

Several species of *Pterospermum* occur in the forests low hills. Fruits of this genus are woody with winged eds.

Guazuma tomentosa, Kunth., is found as an avenue ee. Petals of this plant are concave with two strapaped appendages at the apex of each petal. Staminos alternate with stamens.

The cocoa tree *Theobroma Cacao* belongs to this ımily, and it is cultivated on the Nilgiris.

iliaceae

Plants with stalked leaves and deciduous stipules. owers regular, bi-sexual. Sepals and petals, free, lvate, three to five. Stamens are indefinite, free inserted ı the edge of the receptacle, and free ; anthers introrse, o-celled. Ovary seated on a distinct torus, two- to n-celled. Fruit one- to many-celled, dry or fleshy, hiscent or indehiscent.

This is a tropical family and five genera occur in uth India. *Triumfetta rhomboidea*, Jacq., is a common ed, with globose fruits having hooks. There are veral species of *Corchorus* growing on the plains and *capsularis*, L., is the Jute yielding plant. There are er twenty species of *Grewia* growing in South India.

Rutaceae

Type:—*Citrus Aurantium*, L.

The Orange Tree, *Citrus Aurantium* has spiny branches with alternate, one-foliate leaves that are provided with winged petioles. The leaflet is elliptic or oblong-elliptic, studded with pellucid oil glands, entire or crenate. Flowers axillary, solitary, or in cymes.

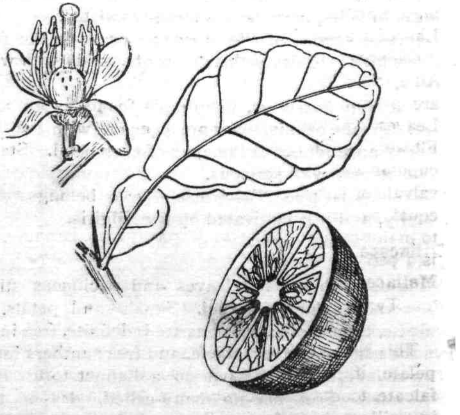


Fig. 320.—*Citrus Aurantium*. A leaf, flower and fruit cut across.

Calyx cup-shaped, five-toothed. Petals usually five, linear oblong, thick, imbricate. Stamens many, inserted round an annular disk. Ovary many-celled with a cylindric single style and capitate stigma. Fruit a many-celled berry with a few seeds immersed in fleshy hairs

growing from the pericarp and filling the cavity. Seeds with coriaceous testa and several embryos.

The well-known Wood Apple tree is *Feronia elephantum*, Corr., and belongs to this Family. Leaves are compound. Flowers unisexual, monoecious, in panicles and dull red in colour. The fruit is a berry with a hard woody rind, containing pulp inside and with seeds imbedded in it.

Aegle Marmelos, Corr., or the Bael tree, *Murraya Koenigii*, Spreng., *Murraya exotica*, L., and *Toddalia asiatica*, Lamk., are other species of this Family.

Characters of the Family:—Trees, shrubs and herbs. All parts of the plant abound in oil glands, though they are prominent in the pericarp of the fruit and leaves. Leaves alternate, exstipulate, simple or compound. Flowers axillary, or terminal cymes or panicles. Calyx cupular with five small teeth. Petals, five, hypogynous, valvate or imbricate. Disk annular or lobed. Stamens equal to, or twice the petals or many. Ovary four- to many-celled; style stout and stigma capitate. Fruit is a berry.

Meliaceae

Type:—*Azadirachta indica*, A. Juss.

(The Neem or Margosa Tree.)

This is a tree with stout trunk. Leaves alternate, exstipulate, imparipinnate; leaflets obliquely lanceolate or falcate, toothed, sub-opposite, nine to thirteen. Flowers in axillary panicles. Calyx five toothed. Petals five, white, narrowly obovate or oblong or spathulate. Stamens form a tube, shorter than the petals, cylindric, widening above, lobed at the apex; anthers within the tube, opposite to the lobes. Ovary three-celled. Fruit one-seeded drupe. Seeds large, non-endospermic and with thick cotyledons.

Cipadessa baccifera, Miq., *Heynea trijuga*, Roxb., and *Melia Azederach* are species of this Family. The trees *Amoora Rohituka*, W & A., *Soymida febrifuga*, Adr Juss,, *Chukrasia Tabularis*, Adr Juss., and *Cedrela Toona*, Roxb., yield valuable timber.

Characters of the Family:—Leaves compound. Flowers bisexual and in panicles. Calyx four- or five-lobed. Petals four or five, free, valvate or imbricate. Stamens five- to ten and filaments united into a tube; anthers introse. Ovary two- to five-celled. Style distinct with a capitate stigma. Fruit a capsule, berry or drupe. Seeds winged or not.

Rhamneae

Type:—*Zizyphus Jujuba*, Lamk.

This is a much branched low tree with stipular thorns.

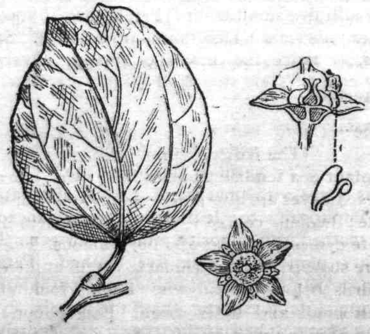


Fig. 321.—*Zizyphus Jujuba*. A leaf, a flower and a section of the flower.

Leaves alternate, simple, short-stalked. ovate-elliptic, unequal at base, three-nerved, entire or finely dentate, green

above, and densely hairy below. Flowers small in axillary cymes, greenish yellow. Sepals, five, valvate, woolly outside and keeled on the inner side. Petals five, small, concave, stamens five opposite the petals. Ovary immersed in a ten-lobed disk, two-celled; style two-branched. Fruit globose, drupaceous, two-seeded.

The other species of *Zizyphus* occurring in South India are *Z. Oenoplia*, Mill., *Z. rugosa*, Lamk., and *Z. xylopyrus* Willd.

Ventilago maderaspatana, Gaertn., is a scandent shrub with winged fruits.

Characters of the Family:—Low trees or scandent shrubs. Leaves simple, with stipular thorns. Flowers small, cymose; calyx has four or five triangular keeled lobes, valvate. Petals four or five concave. Stamens four or five opposite the petals and embraced by them, inserted outside the disk. Disk prominent, filling the calyx tube, entire or lobed. Ovary three-celled immersed in the disk. Fruit adrupe or winged fruit.

Sapindaceae

Type:—*Cardiospermum Halicacabum*, L.,
(The Balloon-vine).

This plant is a tendril climber, with wiry stems and branches. Leaves are alternate, exstipulate, long-stalked, biternate; leaflets coarsely toothed. Flowers small in umbellate cymes, irregular and polygamous. The flower-stalks are slender, but the peduncle is stiff and erect with two tendrils below the flowers. Sepals four, concave, outer pair small and inner large. Petals four, in two pairs, two near the stamens with basal scales and the two remote from the stamens with a crested appendage. Disk unilateral, of two distinct glands, opposite the small lower petals. Stamens eight, eccentric, with hairy,

equal filaments. Ovary three-celled, with one ovule in each. Fruit a three-valved inflated capsule. Seeds black, globular, with a white heart-shaped mark.

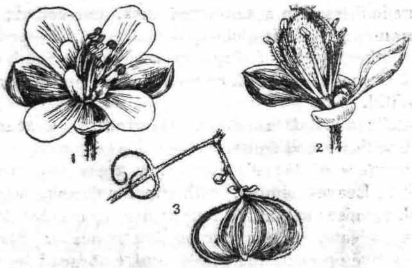


Fig. 322.—*Cardiospermum Halicacabum.* 1, a male flower; 2, a bisexual flower; 3, fruit.

Dodonaea viscosa, L., a low plant, dioecious or polygamous, and *Allophyllus serratus*, Radlk., are species of this Family.

Leguminosae:—This family is the second largest and is cosmopolitan in distribution. It consists of over 6000 species and it is divided into three sub families (1) Papilionatae (2) Caesalpinioideae and (3) Mimosoideae.

Sub. Family:—**Papilionatae**.

Type:—*Tephrosia purpurea*, Pers.

This is a common erect, freely branching, harbaceous weed. Leaves alternate, compound, imparipinnate; leaflets many, opposite, obovate-oblong, parallel-nerved, silky beneath; stipules narrow-lanceolate. Flowers in terminal or leaf opposed racemes; bracts not longer than the pedicels. Calyx bell-shaped, five lobed, lobes

ucminate. Petals papilionaceous, clawed, deep pink; tandard sub-orbicular; wings obliquely oblong. Stamens liadelphous with uniform anthers. Ovary sessile, linear, nany-ovuled; style, flattened, not bearded. Fruit a lattened legume opening by both sutures, obscurely septate. Seeds reniform.

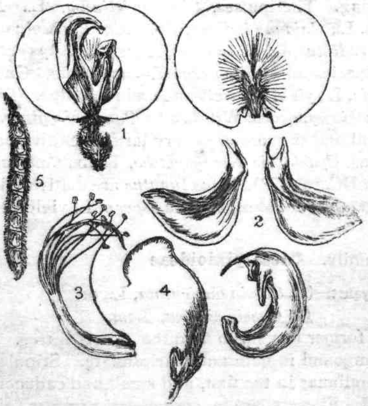


Fig. 323.—*Phaseolus* flower and its parts. 1, a flower; 2, petals; 3, stamens; 4, an ovary; 5, a fruit.

There are over fifty genera and many species of this sub-family growing in Southern India in a wild state. The following are some of the commonest species:—

Crotalaria verrucosa, L., *C. retusa*, L., *C. biflora*, L., *C. juncea*, L., *C. medicaginea*, Lamk., *Indigofera enneaphylla*, L., *I. trita.*, *Tephrosia hirta*, Ham., *Sesbania*

aegyptiaca, Pers., *Zornia diphylla*, Pers., *Aeschynomene indica*, L., *Alysicarpus monilifer*, DC, *A. vaginalis* DC., *Desmodium triflorum*,DC.,*Abrus precatorius*, L.,*Teramnus labialis*, Spr., *Erythrina indica*, Lam., *Butea frondosa*. Koen., *Clitoria Ternatea*, L., *Rhynchosia minima*,DC., and *Derris scandens*, Benth. There are several species of great economic importance and some of them are the following. The pulses, *Cicer arietinum*, L., *Dolichos Lablab*, L., *Cajanus indicus*, Spreng., *Phaseolus Mungo*, L., *P. radiatus*, L., *P. lunatus*, L., are largely cultivated. The species of *Indigofera*, *I. sumatrana*, Gaertn., *I. tinctoria*, L., yield the well-known indigo dye. The seeds of *Arachis hypogaea*, Willd., and *Pongamia glabra*, Vent., yield oil and the former is very largely cultivated. Some such as *Cyamopsis tetragonoloba*, Taub., *Canavalia ensiformis*, DC., and *Phaseolus lunatus* are cultivated for use as vegetables. *Aeschynomene aspera*, L. yields the solar pith.

Sub-family. **Caesalpinioideae**

Type :—(1) *Cassia auriculata*, L., or
(2) *Cassia siamea*, *Lam*.

The former is a shrub and the latter a tree. Leaves are compound in both and paripinnate. Stipules large and semilunar in the first, and small and caducous in the second. Flowers are in corymbose racemes, simple in *C. auriculata* and compound in *C. siamea*. Calyx of five, free, unequal petaloid sepals, concave and quincuncially imbricate. Petals five, clawed, imbricate in bud, with upper petal innermost. Stamens ten, some imperfect and three barren; anthers opening by apical pores. Ovary monocarpellary and one-celled with many ovules. Fruit flat legume opening by both sutures. Seeds without endosperm.

Several species of *Cassia* occur very widely. *Fistula*, L., is a tree bearing drooping large of yellow flowers in profusion during hot weather.

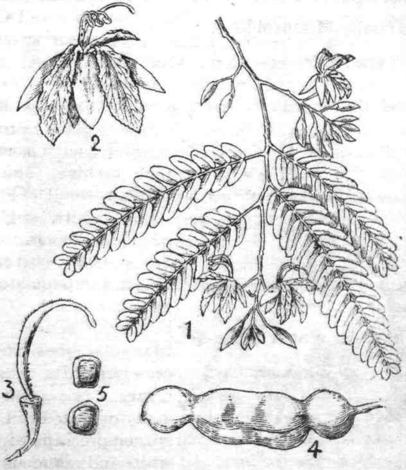


Fig. 324.—*Tamarindus indica, L.* 1, a branch with leaves and flower; 2, flower; 3, ovary and style; 4, fruit; 5, seeds.

Caesalpinia pulcherrima, Swartz; a low much branched tree with red or yellow flowers in racemes is a common garden plant. The filaments are very long in this plant.

The Tamarind tree *Tamarindus indica*, L., of great economic importance is of this Family. The flowers have only three petals with red veins and three stamens. The

fruit has a fleshy mesocarp which in fruit becomes the sweet or acid pulp.

The genus *Bauhinia* is characterised by the possession of a spathaceous calyx and two-lobed or-cleft leaves.

Sub-family-**Mimosoideae.**

Type :—*Acacia arabica*, Willd.
(The Babul Tree)

A small tree with numerous branches, bearing stipular spines. Leaves alternate stipulate, with glands on the rachis, bipinnate leaflets small. Flowers small, sessile, in globose peduncled heads. There are two bracteoles Calyx campanulate with five short teeth. Corolla tubular, yellow with triangular lobes. Stamens are indefinite, exserted Ovary one-celled with many ovules. Fruit stalked, compressed with soft white hairs and indented on both sides and between the seeds and hence moniliform.

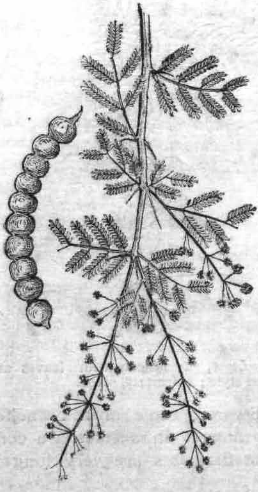


Fig. 325.—*Acacia arabica*. A twig with flower heads and a fruit.

Acacia loeucophlea Willd., having white flowers and *A. Farnesiana*, Willd., with fragrant flowers and turgid legumes with offensive smell are common plants. A

concinna, DC., is a huge climber whose fruits are largely used as soap. The very much branched shrub, *Dichrostachys cinerea* W. & A., with its pretty spikes of red and yellow flowers forms a special feature in scrubby

Fig. 326.—*Mimosa pudica* plant in normal condition.

jungles. Another tall tree, quite conspicous by its flat broad thin fruits and white globose flower heads is *Albizzia Lebbek*, Benth. The plant largely used for hedges *Pithecolobium dulce*, Benth., possesses legumes circinately twisted and seeds with massive arils. *Mimosa pudica* or the Sensitive Plant is fast spreading as a weed on the west coat, in certain parts and in Mysore and Coorg.

Characters of the Family:—The members of this Family are very varied in their habit. Herbs, shrub, climbers and trees. Leaves simple or compound. Flowers bisexual regular or irregular. Sepals free or united. Petals five, free. Stamens ten or many, free or united. Ovary monocarpellary one-celled and many-ovuled. Fruit is a legume.

Papilionatae:—Flowers papilionaceous, standard being the outermost in the flower bud. Stamens mon- or di-adelphous.

Caesalpiniodeae:—Flowers regular. Petals regular, clawed, uppermost petal is innermost in the flower bud. Stamens ten, free, all or only a few fertile.

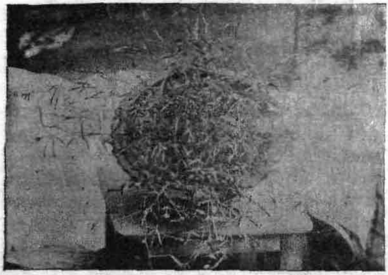


Fig. 327.—*Mimosa pudica* after disturbance of the plant.

Mimosoideae:—Flowers small, in heads or spikes, bisexual, but also with male and barren flowers in the same head or spike in some genera. Sepals and petals five valvate. Stamens definite or indefinite, exserted and free.

The most marked feature of Leguminosae is undoubtedly the fruit, which is a legume in most cases. But there is a large amount of variation in the structure of the fruit. We have dehiscent as well as indehiscent dry fruits. The pericarp is pulpy in some cases, and in others the fruit is turgid. There are also samaras. In spite of these variations, they are all monocarpellary.

This Family comprises more useful plants than any other, except probably Gramineae.

Combretaceae

Type:—*Terminalia Arjuna*, W & A.

This is a large tree with smooth greenish white bark peeling off in large pieces. Leaves alternate or sub-opposite, simple and exstipulate, oblong to elliptic-oblong, with short petioles. There are also two glands at the base of the leaf close to the petiole, one on each side. Flowers are in spikes, with short bracteoles. Calyx bell-shaped with five teeth. Petals not found. Stamens ten, inserted on a disk clothed with hairs.

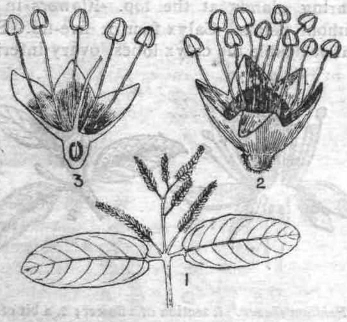


Fig. 328.—*Terminalia Arjuna*. 1, a bit of a branch; 2, a flower; 3, section of a flower.

Ovary inferior, one-celled with two or three pendulous ovules. Fruit a fibrous woody drupe, with five projecting wings. Seed single and without endosperm.

If the type tree is not available *Terminalia Catappa*, L. may be taken as the type. In this tree branches are in whorls and grow long and bear short-stalked, obovate,

large leaves, closely at the ends of twigs. Flowers are in simple spikes and the fruit is compressed, ovoid and two-ridged.

The species *Terminalia Chebula*, Roxb., is the Myrabolam Tree. The scandent shrub *Calycopteris floribunda* is common on the West coast. *Quisqualis indica*, L., a climbing shrub with long-tubed flowers is of this Family commonly cultivated in gardens.

Characters of the Family:—This is a very well defined Family. Trees, shrubs, erect or scandent. Leaves alternate, opposite, exstipulate, simple, and the petioles often bearing glands at the top. Flowers in spikes, small without petals. Calyx four or five-fid. Stamens free, equal or double the calyx lobes, ovary inferior, one-

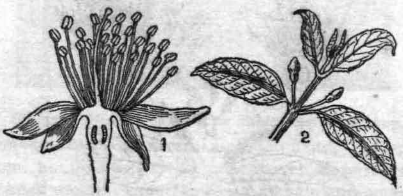


Fig. 329.—*Psidium Guava*. 1, section of a flower; 2, a bit of a branch.

celled with two or more pendulous ovules. Fruit is usually dry and indehiscent, in some drupaceous and winged. Seed single, cotyledon convolute, without endosperm.

Myrtaceae

Type:—*Syzgium Jambolanum*, DC. or *Psidium Guyava* L.

Plants of this Family are herbs, shrubs or trees. Leaves opposite, simple, exstipulate, entire, gland-dotted

with an intra-marginal nerve. Flowers regular, bisexual, solitary, in cymes or cymose panicles. Calyx, superior with four or five teeth. Petals four or five, free, inserted at the margin of the disk, falling away in one piece. Stamens many, filamens long, *conspicuously* coloured, folded in the bud. Ovary inferior, two-celled with one or many ovules. Fruit is a berry with the persistent calyx lobes on its top, one- or two-celled, one- or many-seeded.

Cucurbitaceae

This is a very well defined tropical Family consisting mostly of climbers, with hollow stems and simple

Fig. 330.—*Cucurbita moschata.* 1, branch with tendrils; 2, a female flower; 3, a male flower showing the stamens.

or branched tendrils. Leaves simple, alternate, exstipulate, cordate at base, entire or palmately lobed and with coarse hairs. Flowers yellow or white,

monoecious or dioecious, solitary or racemed. The calyx-tube is adnate to the ovary and so the calyx lobes are superior. Sepals and petals five. Petals united, rarely free. In male flowers, the stamens are three attached to the calyx tube; anthers free or cohering, lobes conduplicate or flexuose, and the connective produced beyond the apex of the anther or not. In the female flower the ovary is inferior, three carpellary, one- or three-celled with parietal placentas. Fruit is a berry or pepo. Seeds many flat.

This Family is very well represented in South India. Many are wild and some are cultivated.

Coccina indica W. & A., a dioecious creeper is found everywhere in hedges. *Citrullus Colocynthis*, Schrad., is a common weed found in sandy lands. *Blastania Garcini*, Cogn., with its pretty tiny scarlet fruits, and large stipules like bracts and *Melothria maderaspatana*, Cogn., with its round bright-red berries are occasionally met with all over South India.

The cultivated Gourds, Melons, Cucumbers belong to this Family. The Snake-gourd *Trichosanthes anguina*, L., has fimbriate petals and the Bitter-gourd *Momordica Charantia*, L., is easily recognised by its tubercled fleshy fruits. The Pumpkins are *Cucurbita maxima*, Duch, C. Pepo, DC.,. The White Gourd-Melon is *Benincasa cerifera*, Savi.

Aizoaceae

This is a small Family embracing a few species which are weeds.

The most troublesome weed *Trianthema Portulcastrum*, L., a perennial prostrate weed is of this Family. Leaves, opposite, entire, unequal, round or obovate, petiolate, with petioles somewhat dilated and mem-

branous at the base, and that of the smaller leaf forms a pouch in which the flowers are situated. Flowers solitary sessile, within the petiolar pouch. Calyx consists of five deep lobes, bearing a short process at the apex and

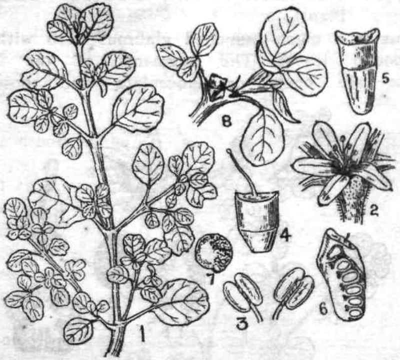


Fig. 331.—*Trianthema Portulacastrum.* 1, a branch; 2, a flower; 3, stamens; 4, ovary; 5, fruit; 6, section of fruit; 7, seed; 8, flower bud at the node.

coloured light pink or white within. Petals are not present. Stamens ten to twenty. Ovary is free, superior, sessile and truncate, style single. Fruit a capsule, membranous below, and hardened into a cap above, which gets detached by circumcissile dehiscence. Seeds black reniform or orbicular, striated.

Trianthema decandra, L., *T. triquetra*, Rottl., are other weeds of common occurrence. *Mollugo lotoides*, O.Kze., is extremely common in clayey soil and tank beds, and it is covered densely with stellate hairs. *M. oppositifolia*,

L., and *M. pentaphylla*, L., are common weeds of waste places in the plains.

Umbelliferae

Type:—*Coriandrum sativum*, L., (The Coriander Plant).

This is a much branched glabrous herb with decompound leaves. The segments of the lower leaves are ovate or lanceolate and those of

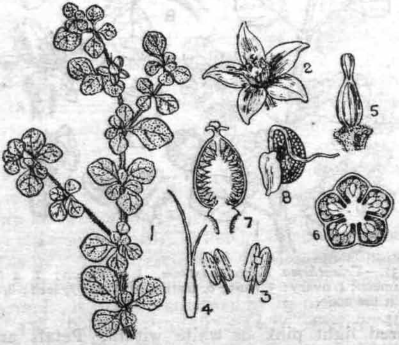


Fig. 332.—*Mollugo lotoides*. 1, a branch; 2, a flower; 3, stamens; 4, a staminode; 5, an ovary; 6, a fruit cut across; 7, a fruit cut longitudinally; 8, a seed with the appendage.

the upper are linear. Flowers in compound umbels, and the outer flowers have larger petals. Calyx five, small unequal teeth. Petals five, white or white tinged with red, unequal, emarginate or deeply bifid, with a median fold or not, epigynous. Stamens five, alternating with the petals and epigynous. Ovary inferior, two-celled

with an ovule in each. Fruit subglobose with ridges and faint oil canals or vittae, breaking into mericarps when ripe; mericarp concave on the inner face and has one pendulous seed.

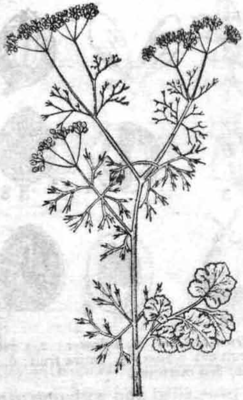


Fig. 333.—A branch of *Coriandrum sativum*. Note the umbels of flowers.

Umbelliferae contain several species of economic importance. *Carum copticum*, Benth and Hook., yields thymol; cummin seeds used as a condiment are the fruits of *Cuminum cyminum*, L.,; *Narthex* and *Ferula* yield the gum-resin asafoetida. Most of the species flourish on hills and *Centella asiatica*, Urban., occurs as a weed in wet places.

Characters of the Family:—Herbs with alternate, simple or compound leaves having petioles with dilated

bases. Flowers bisexual in simple or compound umbels. Calyx of five minute teeth. Petals five, free, inserted outside an epigynous disk, caducous. Stamens five, alternating with the petals, filaments inflexed in bud.

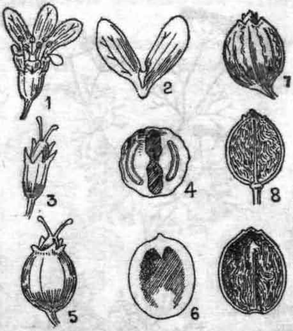


Fig. 334.—*Coriandrum sativum*. 1, a flower; 2, a petal; 3, the calyx and pistil; 4, fruit cut across; 5, entire fruit; 6, segments of the fruit; 7, old fruit; 8, a mericarp.

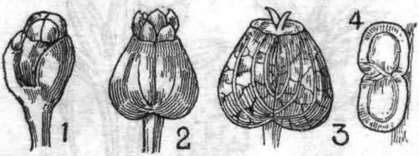
Ovary inferior, two-celled and with one pendulous ovule in each. Fruit is dry breaking into two mericarps. Seeds with endosperm.

Rubiaceae

Types:—*Morinda tinctoria*, Roxb.,
Oldenlandia umbellata, L.,

This is a tree with thick, white, irregularly furrowed bark, and crooked branches. Leaves opposite, simple, shortly petioled, with connate interpetiolar stipules, glabrous, elliptic-oblong. Flowers white, in heads, on leaf-opposed long peduncles. Calyx of all the flowers

ed. Corolla tubular, five-lobed, superior. Stamens e epipetalous. Ovary two- or four-celled. Fruit bose, fleshy, consisting of the fused enlarged calyces all the flowers, with many druplets or pyrenes. Seeds th endosperm.



g. 335.—*Centella asiatica.* 1, a flower bud; 2, a flower; 3, a fruit; 4, section of fruit.

Oldenlandia umbellata, L., is an annual weed with any branches. Leaves linear, sessile, opposite with e interpetiolar stipules cut into bristles. Flowers in ymose umbels, or long axillary peduncles, tetramerous. vary inferior, two-celled with many ovules. Fruit a lobose capsule, with persistent calyx-teeth on its top. eeds are small and many.

Randia dumetorum, Lamk., has large white flowers or hort branches which are armed with decussate spines. *lectronia parviflora*, Bedd., a low spiny shrub is a ommon plant in scrubby jungles. *Borreria hispida*, K. ch., is a weed of dry cultivated fields. *Pavetta indica* .. also occurs widely. Several species of *Psychotria*, *asianthus* and *Ixora* are met with on the Hills of both Vestern and Eastern ghats.

Among economic plants of great value the introduced *inchona succirubra*, Pavon., and *C. officinalis* Hook., ield quinine, and the Coffee plant is *Coffea arabica* L.

The plants *Rubia cordifolia*, L., and *Oldenlandia umbellata*, L., yield red dyes.

Characters of the Family:—This is a large Family with about 5000 species. Herbs, shrubs and trees.

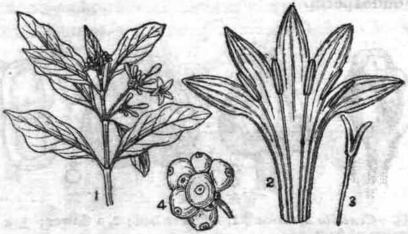


Fig. 336.—*Morinda tinctoria*. 1, a branch; 2, corolla laid open to show the epipetalous stamens; 3, style; 4, a fruit.

Leaves opposite or whorled, simple, with inter-petiolar stipules. Flowers regular, tetra- or penta-merous. Ovary two- to ten-celled. Fruit berry, capsule or drupe. Plants of this Family are easily recognised by the inferior and interpetiolar stipules found between two opposite or whorled leaves.

Compositae

Type :—*Vernonia cinerea*, Less.

A perennial herb with very variable leaves, though usually ovate or lanceolate and with undulately toothed margin. Heads in terminal lax corymbs. Flowers all tubular. The involucral bracts are in many series, linear-lanceolate. Corolla narrowly tubular, pink. Stamens five with syngenesious anthers, epipetalous. Achenes four or five angled clothed with short hairs and two rows of white pappus hairs.

The common weed *Tridax procumbens*, L., an introduced South American weed may also be examined as a type.

This is a perennial herb with straggling hairy branches some of them ending in heads. Leaves opposite, simple, ovate or ovate-lanceolate, irregularly coarsely toothed

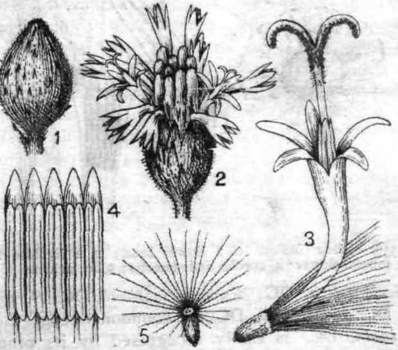


Fig. 337.—*Vernonia cinerea.* 1, a young flower head 2, a flower head with flowers open; 3, a tubular flower; 4, anthers; 5, an achene.

and hairy on both surfaces. Heads on long peduncles, solitary, heterogamous and rayed. Involucral bracts outer shorter and hairy. Receptacle flat, paleate. Ray flowers cream-colour or light yellow, ligulate, deeply three-partite, female. Disk flowers bisexual tubular. Corolla of tubular flowers bell-shaped, five-lobed. Stamens five, epipetalous with syngenesious anthers. Ovary inferior, one-celled, one-ovuled. Style arms of tubular

flowers hairy on the inner surface. Fruit is an oblc achene, silkily hairy and crowned by the persist feathery bristles of the pappus.

This family is one of the largest families and is wid spread. It has over 12000 species. Many species oc in South India.

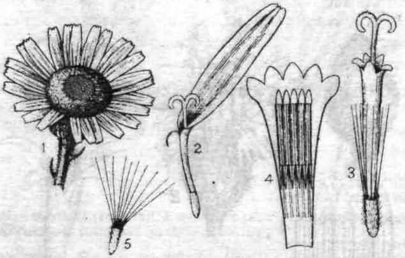


Fig. 338.—*Vicoa indica.* 1, a flower head; 2, a ligulate flow 3, a tubular flower; 4, corolla and stamens; 5, an achene.

Vicoa indica, DC., *Blumea wightiana*, DC., *B. amp tens*, DC., *B. bifoliata*, DC., are common weeds. *Lact runcinata*, DC., is easily recognised by its pinnat radical leaves and heads with ligulate flowers or Amongst introduced weeds, *Lagasca mollis*, C *Flaveria australasica*, Hook., and *Sonchus oleraceus*, are prominent. *Acanthospermum hispidum*, DC. a So American weed is spreading in parts of South Cana North Malabar and Bangalore and it is a very rec introduction.

Xanthium strumarium, L., is another gregarious w occasionally met with in fallow paddy fields and t beds. *Grangea maderaspatana*, Poir., *Eclipta a* Hassk., are sure to be found in moist situations. *Sphaer*

thus indicus, L., and *S. amaranthoides*, Burm., are weeds of the paddy fields.

Characters of the Family :—Herbs, shrubs, rarely trees. Leaves exstipulate, alternate. Flowers small on dilated ends of the peduncles forming heads. Heads all tubular, bisexual flowers, or the ray flowers ligulate and female and disk flowers bisexual. Corolla epigynous ligulate in ray and tubular in disk flowers. The tublar corolla bell-shaped, five-lobed and lobes with marginal veins. Stamens five, epipetalous, with free filaments and syngenesious anthers; anther-lobes tailed or not; connective produced upwards. Ovary inferior, one-celled, one-ovuled. Fruit achene crowned with pappus hairs. Seed without endosperm.

The plants of this Family are very aggressive and successful in occupying the land. The compact massing of the flowers into heads, the simple effective floral mechanism ensuring protection of honey and pollen and cross-pollination until the last possible moment and the pappus bearing achenes are favourable factors.

Sapotaceae

Type :—*Bassia longifolia*, L.

A large tree abounding in milky juice. Leaves simple alternate, stipulate, linear-lanceolate, entire, acute, glabrous and clustered near the ends of branches. Flowers clustered like the leaves at the ends of branches. Calyx of four sepals in two whorls. Corolla campanulate, fleshy, six- to twelve-lobed. Stamens epipetalous, six to twenty, in two rows one above the other; anthers lanceolate with the connectives produced above the anthers. Ovary six- or more-celled, clothed with fine hairs. Fruit a berry with one or two seeds. Seeds with polished testa and non-endospermic.

Mimusops Elengi, L., is grown as an ornamental tre
and *M. hexandra*, Roxb., occurs in scrubby jungles.

Apocynaceae

Members of this Family are herbs, shrubs or trees anc a few are climbers with milky juice. Leaves simple

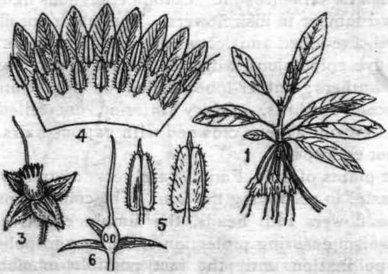


Fig. 339.—*Bassia longifolia.*—1, a branch; 2, a flower; 4, corolla an *stamens; 5, stamens; 6, ovary cut longitudinally.*

opposite or whorled, entire. Flowers bisexual, in cymos inflorescences. Calyx five-toothed and imbricate. Coroll tubular, five-lobed, lobes contorted. Stamens five, epi petalous, with short filaments and sagittate anthers *Ovary two-celled united or separated into two distinc* carpels. Fruit berry or follicle. Seeds comose, winge or not.

The weed *Lochnera pusilla*, K. Schum., and the garde plant *Lochnera rosea*, belong to this family. *Neriun Odorum*, Soland., is a shrub generally planted for it flowers.

Wrightia tinctoria, Br., is a low deciduous tree wit

milky juice. Flowers of this tree occur in diffuse dichotomous cymes and the petals bear fimbriate coronas.

Asclepiadeae

Type:—*Calotropis gigantea,* R. Br.

A shrub abounding in milky juice. The leaves and stems are covered with appressed white cottony tomentum. Leaves large, exstipulate, shortly stalked, oblong

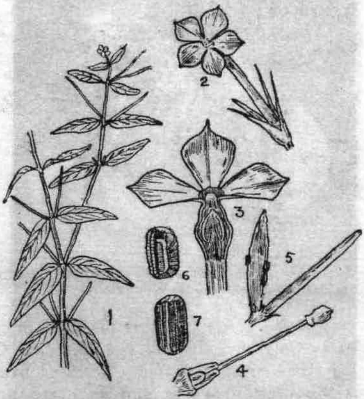


Fig. 340.—*Lochnera pusilla.* 1, a branch; 2, a flower; 3, section of the flower; 4, pistil; 5, follicles; 6 and 7, seeds.

or elliptic-oblong, thick, entire. Flowers in lateral umbels. Pedicel fine and covered with tomentum. Calyx five-partite and segments triangular and short. Corolla rotate, five-lobed; lobes pink or bluish pink, or white, valvate and broadly triangular. Stamens five united into a tube and with five laterally compressed plate-like

coronas; anthers broad, membranous, united with the pentagonal stigma. Pollen is massed together as pollen-masses or pollinia, and one pollinium in each anther-cell. Pollinia are connected in pairs by five black stalks

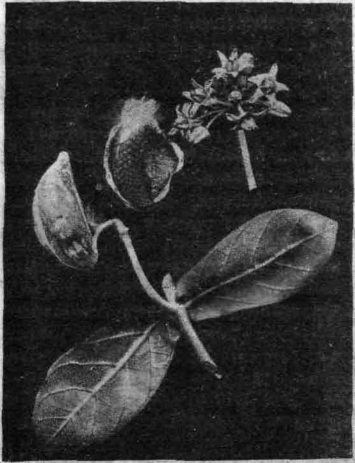


Fig. 341.—*Calotropis gigantea.* A branch, inflorescence and follicle.

called **translators**. Ovary two-celled, carpels free, styles free; stigma large and pentagonal, peltately attached to the styles. Fruit of inflated follicles, one or rarely two. Seeds flat and comose.

Several species of this family are twiners or scandent shrubs. *Daemia extensa*, Br., *Leptadenia reticulata* W & A., and *Hemidesmus indicus* are common twiners.

The genus *Ceropegia* has a peculiar tubular corolla inflated below and above, and ending above in five

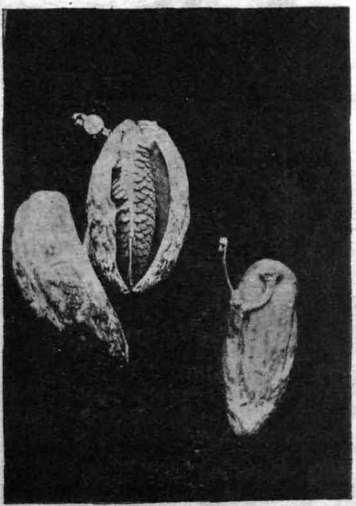


Fig. 342.—*Calotropis gigantea* follicles.

lobes which cohere in different ways. Species of *Hoya*, *Boucerosia umbellata*, W & A., *Caralluma adscendens*, Br., are xerophytes. The last two have green fleshy stems without leaves.

Characters of the Family :—Herbs and twining shrubs with milky juice. Leaves opposite, simple, exstipulate. Flowers regular, pentamerous, in umbels. Calyx divided down to its base into five segments. Corolla five-lobed, rotate, tubular and in some with corona. Stamens

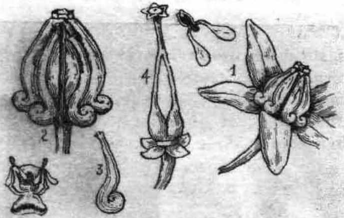


Fig. 343.—*Calotropis gigantea.* 1, a flower; 2, staminal column with corona; 3, corona 4, pistil.

Fig. 344.—*Boucerosia umbellata.*

five, united so as to form a fleshy tube and with outgrowths at the back (corona); anthers free or united to the

stigma; pollen-grains in masses as pollinia and each pollinium may have a stalk (caudicle) and a gland (corpuscle.) Ovary is superior, free, two-celled; ovules many. Fruit consists of two follicles, but often only one is developed. Seeds flat and comose.

Boragineae

Herbs, shrubs or trees. Leaves are simple, exstipulate and alternate. Inflorescence scorpioid or suppressed dichotomous cymes. Flowers regular, bisexual. Calyx five-partite, persistent. Corolla five-lobed, tubular. Stamens five, epipetalous with short filaments. Ovary

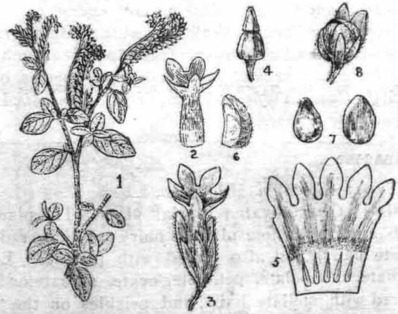


Fig. 345.—*Holiotropium ovalifolium.* 1. a branch; 2, a corolla; 3, a flower; 4, an ovary; 5, corolla cut open; 6 & 7, nutlets 8, a fruit.

superior, two- to four-celled, with one ovule in each cell, Style gynobasic. Fruit is either a drupe or it divides into four nutlets.

Heliotropium ovalifolium, Forsk., *Trichodesma indicum*. Br., *Heliotropium indicum*, L, *Coldenia procumbens*, L.,

Ehretia buxifolia, Roxb., are of wide occurrence. The trees *Cordia Myxa*, L., *C. monoica*, Roxb., are fairly common.

Convolvulaceae

Herbs or shrubs mostly twining. Leaves simple, alter nate, exstipulate, petiolate. Flowers regular, bisexual solitary or cymose. Sepals five, free, imbricate. Coroll showy, rotate, bell- or funnel-shaped. Stamens fiv unequal, epipetalous. Ovary superior, two- or four-celled with four ovules. Fruit a capsule. Seeds with scant endosperm and folded foliaceous cotyledons.

Evoloulus alsinoides, Wall., growing amidst grass i waste places, and several species of Ipomoea, such as . *sepiaria, I eriocarpa, I pestigridis*, are species of thi Family. *Cuscuta reflexa*, Roxb., and *C. chinensis*, Lamk are parasitic twiners.

Solanaceae

Type:—*Solanum Melongena*, L.

This is the cultivated Brinjal plant. The plant is shrub and the whole plant is hairy and covered wi stellate hairs, and also armed with prickles. Leav alternate, exstipulate, petiolate, ovate, sinuate or lobe covered with stellate hairs, and prickles on the vein unequal at base. Flowers in extra-axillary helico cymes, only one flower being perfect. The calyx five-lobed, stellately hairy outside, persistent and gro with the fruit, sometimes prickly. Corolla is violet bl rotate, five lobed (sometimes six to eight), stellate hairy outside, between the folds and on the plai Stamens are equal to the corolla lobes, epipetalo filaments short, and anthers open by apical pores. Ov

superior two-celled and many-ovuled. Fruit is a two-celled berry. Seeds flat compressed.

This plant exhibits a certain amount of variation in its flower under cultivation. On the same plant, we find corollas with lobes from five to eight, and as many stamens. The fruits also have many irregular cavities due to unequal growth and development of the placenta.

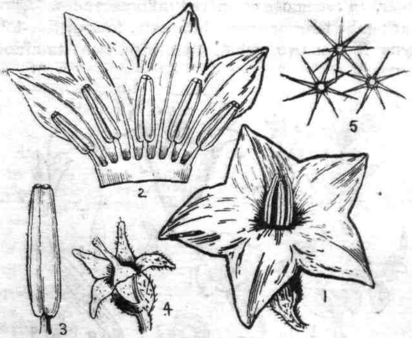


Fig. 346.—Floral parts of *Solanum Melongena*. 1, a flower; 2, a corolla cut open; 3, a stamen; 4, calyx and pistil; 5; stellate hairs.

Several species of *Solanum* such as *S. xanthocarpum*, L., *S. nigrum*, L., *S. torvum*, Sw., are common.

The plants *Capsicum frutescens*, L., and *C. annuum*, L., yield the chillies, and the Tobacco plant is *Nicotiana Tabacum*, L.,

The potato, *Solanum tuberosum* and the Tomato, *Lycopersicum esculentum* are largely cultivated. The Thorn-apple, *Datura fastuosa* and *Withania somnifera* are

medicinal plants and the former is also a poisonous plant.

The flowers of *Physalis*, *Withania* and *Nicandra* have enlarged membranous calyces enveloping the fruit.

Scrophularineae

Herbs and shrubs, some are root parasites. Leaves alternate, opposite or whorled, exstipulate. Flowers irregular, in racemose or mixed inflorescences. Corolla tubular; tube long or short, bilabiate, four-or five-lobed. Stamens four or two, when two with two staminodes.

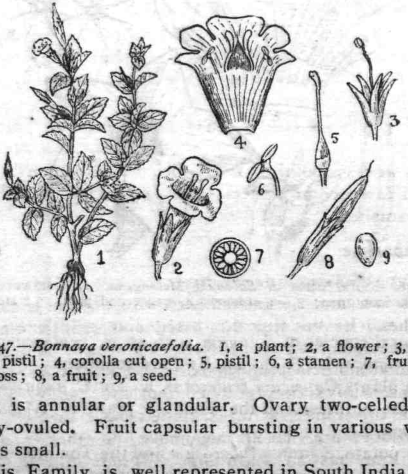
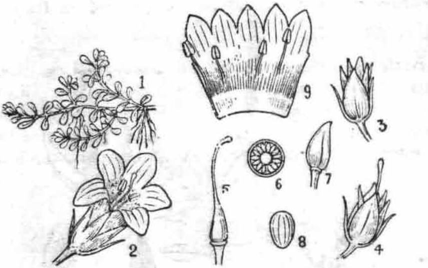


Fig. 347.—*Bonnaya veronicaefolia.* 1, a plant; 2, a flower; 3, calyx and pistil; 4, corolla cut open; 5, pistil; 6, a stamen; 7, fruit cut across; 8, a fruit; 9, a seed.

Disk is annular or glandular. Ovary two-celled and many-ovuled. Fruit capsular bursting in various ways. Seeds small.

This Family is well represented in South India and most of them are weeds in marshy places. Paddy

elds abound in *Stemodia viscosa*, *Illysanthes parviflora*, *'onnaya veronicaefolia*, Spreng., *Dopatrium nudicaule*, am., *D. junceum*, Ham., *D. lobelioides*, Benth. Of marsh



ig. 348.—*Moniera cuneifolia.* 1, a plant; 2, a flower; 3, a flower bud; 4, calyx and pistil; 5, pistil; 6, fruit cut across; 7, a fruit; 8, a seed.

'eeds we may mention *Moniera cuneifolia*, Michx., species of *Limnophila*. Species of *Sopubia* and *Striga* are oot-parasites.

.canthaceae

Type :—*Rungia repens*, Nees.

This is a much branched herb with slender glabrous ranches. Leaves opposite, exstipulate, elliptic or elliptic lanceolate, shortly petioled. Flowers in one sided pikes, with bracts and bracteoles. Bracts have scarious argins. Calyx deeply lobed into five narrow lobes. 'orolla two-lipped, with two epipetalous stamens. The nther-lobes are placed one above the other, and the ower lobe has an appendage. The fruit is a small ompressed capsule. Seeds flat rounded.

This Family is not of much economic importance.

Several species occur as weeds. Species of *Strobilanthes* grow on higher elevations on the Hills and form a special feature of the landscape.

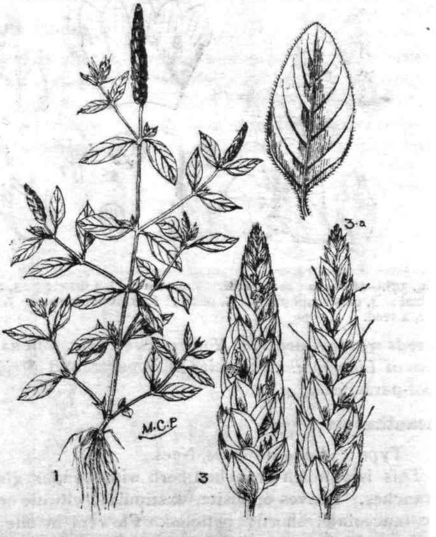
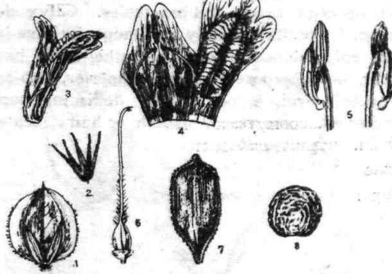


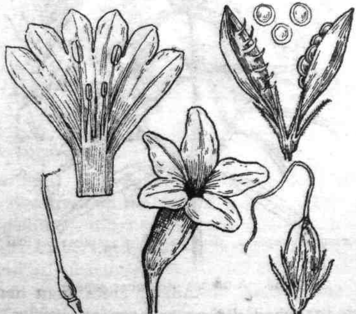
Fig. 349.—***Rungia repens.*** **1, plant; 3 and 3-a, spikes; a leaf is show separately.**

Hygrophila spinosa, T. And., an erect stout herb wit long spines at the nodes occur in moist ditches amids paddy fields. Other plants of this family of commo occurrence are *Andrographis echioides*, Nees., *Barleri*

onitis, L., *Blepharis Molluginifolia*, Pers., *Ruellia strata*, Jacq., and *Justicia procumbens*, L.



. 350.—*Rungia repens*. 1, bract and bracteoles; 2, calyx; 3, corolla; corolla laid open; 5, stamens; 6, ovary; 7, fruit; 8, seed.



. 351.—*Ruellia patula*. 1, corolla opened to show the stamens; 2, fruit burst open showing the retinacula and seeds; 3, pistil; 4, corolla; 5, fruit.

Characters of the Family :—Herbs and shrubs. Leaves opposite, exstipulate, simple and the nodes swollen. Flowers regular or irregular, in cymes, spikes or racemes with bracts and bracteoles. Calyx deeply five-lobed. Corolla equally or unequally five-lobed. Stamens epipetalous four or two; anther-lobes parallel and near, or superposed. Ovary superior, two-celled, many-ovuled, Fruit a loculicidally dehiscing capsule. Seeds discoid, compressed, smooth or hairy, seated on retinacula, without endosperm.

Labiatae

Type:—*Leucas aspera*, Spreng.

Fig. 352.—A branch of *Leucas aspera.*

A much branched, diffuse, annual with square, hairy stems. Leaves opposite, simple, exstipulate, sessile or shortly stalked, linear, coarsely crenate, and hairy on

both the surfaces. Flowers sessile, in verticillasters in the axils. Bracts linear, acute, with long hairs on the margins. Calyx is monosepalous, persistent, tubular, bent and constricted below; the upper portion of the tube is ribbed and hairy, but the lower half is glabrous and membranous; the mouth of the tube is oblique, with the small upper teeth projecting above. Corolla white, labiate; upper lip narrow, densely hairy outside, lower

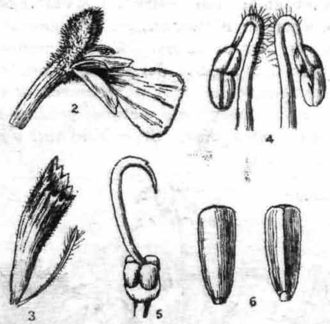


Fig. 353.—*Lencas aspera.* 2, corolla; 3, calyx and bract; 4, stamens; 5, pistil; 6, nutlets.

lip broad, flat, three-lobed, the middle lobe being the largest, obovate and the lateral smaller. The stamens are epipetalous, didynamous and included within the upper lip; anthers red. Ovary is superior, deeply four-lobed and is surrounded by a lobed disk. The style is long and gynobasic. Fruit of four oblong nutlets, rounded at the back and angled inside.

Plants of this Family are all aromatic and strongly scented. The sweet Basil, *Ocimum Basilicum*, L., and the

sacred Tulsi, *O. Sanctum*, L., are examples. *Anisomeles malabarica*, R. Br., *Ocimum adscendens*, *Geniosporum prostratum* are common weeds. Many species of *Leucas* occur on both the plains and on the hills. In some parts of the Presidency the plant *Leonotis nepetaefolia*, with large verticillasters, and scarlet or deep orange corollas is common.

Characters of the Family:—Scented herbs and shrubs. Stem quadrangular and hairy. Leaves exstipulate, opposite or whorled. Flowers irregular, bisexual, labiate, in cymes or verticillasters. Calyx monosepalous, tubular, irregular or regular, persistent. Corolla labiate, tubular; stamens epipetalous, didynamous or all equal, rarely two only; connective sometimes produced. Ovary superior with a lobed disk. Style bifid and gynobasic. Fruit of four nutlets.

Amarantaceae

Type:—*Achyranthes aspera*, L.

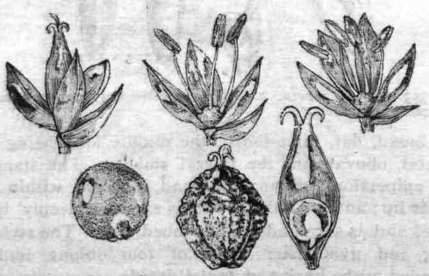


Fig. 354.—*Amarantus viridis*. 1, female flower; 2 and 3, male flower 4, seed; 5, fruit; 6, ovary with one ovule.

This plant produces a few straggling branches and the stem is rounded and striate. Leaves simple, exstipulate, opposite, petioled shortly, rotund or obovate, wavy margin, and hairy on both surfaces. Flowers in terminal spikes, stiffly deflexed and crowded. Bract and bracteoles spinescent at their tips, persistent. The perianth consists of five ovate-oblong or lanceolate,

Fig. 355.—Full plant of *Gomphrena decumbens*. A spike is shown separately.

shining, glabrous sepals with spinescent apex and membranous margins. These become hardened and persist with the fruit. Stamens five, alternating with five, truncate, fimbriate staminodes. Fruit indehiscent with a membranous hardened pericarp. Seed cylindric.

Amarantus gangeticus, L., is largely cultivated. Many species are weeds and the common weeds are the following. *Amarantus viridis*, L., *A. spinosus*, L., *Celosia argentea*, L., (most abundant in dry fields and conspicuous on account of the glistening white spikes, pinkish at first). *Aerua lanata* Juss., A. *javanica*, Juss and *A. Monsonia*, Mart.,

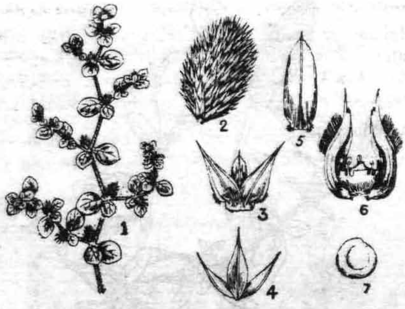


Fig. 356.—*Alternanthera echinata.* 1. a branch; 2, a spike; 3 and 6, flowers; 4, bracts and bracteoles; 5, a perianth lobe; 7, a seed.

Alternanthera echinata is an Amarantaceous weed, evidently introduced very recently within the last five years. Some six years ago there was not a single plant at Bangalore and Coimbatore, where they are now spreading fast. *Gomphrena decumbens*, another plant now found as a bad weed everywhere in Madras City, made its appearance some fifteen years ago. Then only two or three plants were noticed in Egmore in Halls road, close to the Museum.

Alternanthera sessilis, Br., grows in damp places. *upalia atropurpurea*, Moq., grows in hedges. In this owers are grouped in cymes of three, and the two lateral ecome hooked spines and remain attached to the iddle one and persist with the fruit.

Characters of the Family:—Herbs or shrubs. Leaves mple, exstipulate, alternate or opposite. Flowers bi- exual or unisexual, monoecious, in spikes or clusters. erianth of five scarious members. Stamens one to five, aminodes present or not. Ovary one-celled with one r many ovules, erect or suspended. Fruit a membranous tricle. Seeds usually orbicular, black, polished and ompressed; embryo coiled in a floury endosperm.

uphorbiaceae

Type:—*Phyllanthus maderaspatensis*, L.,
Euphorbia thymifolia.

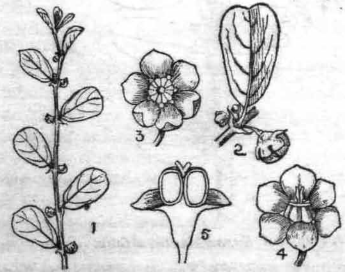


Fig. 357.—*Phyllanthus maderaspatensis*. 1, a branch; 2, a leaf and two flowers; 3, male flower; 4, a female flower; 5, fruit cut through.

Phyllanthus maderaspatensis, L., is a free, branching annual and the youngest branches simulating pinnate

leaves. Leaves small, alternate, bifarious, shortly petioled with lanceolate, peltate stipules, obovate-cuneate, truncate or rounded at apex, often mucronate, and the nerves are conspicuous on the lower surface of the leaf. Flowers unisexual, monoecious; male flowers very small, sessile and clustered in the axils; female flowers are

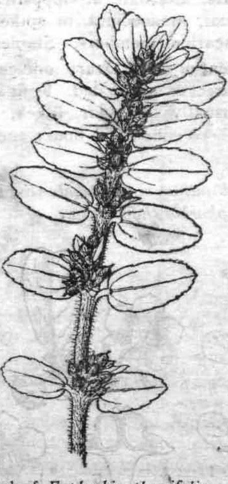


Fig. 358.—A branch of *Euphorbia thymifolia.*

larger, solitary, stalked. Sepals in both the flowers six, obovate, with white margins. Stamens three, filaments united. Ovary superior, three-celled, with two ovules in each. The fruit is a capsule with three lobes. Seeds trigonous, and dorsally rounded.

Euphorbia thymifolia is a creeping small plant abounding in milky juice. Leaves small, opposite, exstipulate with small stipules. Flowers unisexual, monoecious and collected together into inflorescences simulating single

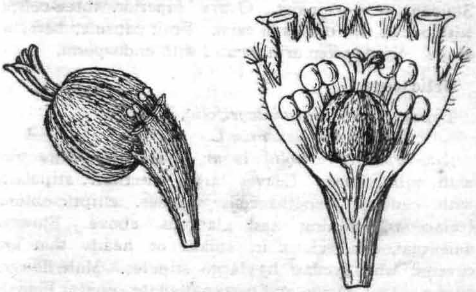


Fig. 359.—Inflorescence of *Euphorbia thymifolia*. 1, female flower; 2, cyathium open.

flowers, called cyathia. A cyathium consists of a five-lobed tubular involucre enclosing a solitary stalked ovary and a number of stamens. The ovary represents a female flower and each stamen is a male flower. Between the limbs of the involucre there is a gland. Fruit is a hairy capsule having three cavities and one trigonous seed in each.

There are many species of Euphorbias such as *Euphorbia rosea*, Retz., *E. corrigioloides*, Boiss., *E. antiquorum*, L., and *E. tirucalli*. Other plants of this Family are *Chrozophora plicata*, *Jatropha curcas*, L., *Phyllanthus Emblica* L., *P. reticulatus*, Poir., *Ricinus communis*, L., *Trewia nudiflora*, and *Tragia involucrata* a creeper and a stinging nettle and *Acalypha indica*, L.

Characters of the Family:—Herbs, shrubs and trees with milky juice. Leaves stipulate, alternate or opposite and simple. Flowers unisexual, monoecious, small, arranged in various ways. Perianth single, five-lobed. Stamens few or many. Ovary superior, three-celled, with one or two ovules in each. Fruit capsule, berry or drupe. Seeds often arillate and with endosperm.

Urticaceae

Types:—*Artocarpus integrifolia*, L.
Ficus bengalensis, L.

Artocarpus integrifolia is an evergreen large tree with milky latex. Leaves large, alternate, stipulate, with caducous, spathaceous stipules, elliptic-oblong coriaceous, shining and glabrous above. Flowers unisexual, monoecious, in spikes or heads that are covered when young by large stipules. Male flowers with a single stamen and two spathulate sepals. Female flower a tubular perianth, united to a concave receptacle with the ovary at the bottom. The female spikes grow into the jack-fruit, which consists of an enlarged axis covered with the fleshy perianth and carpels with hardened flat spinescent apices.

Ficus bengalensis, L., is a large tree with aerial roots capable of indefinite extension, abounding in milky juice in all its parts. Leaves simple, alternate, with large stipules, oblong, entire, obtuse. Flowers unisexual, small, on the inner surface of a hollow receptacle, called hypanthodium, syconium or fig. Male flowers many, near the mouth of the receptacle, each with four sepals and a stamen. Female flowers with four sepals and an ovary with an ovule. Gall flowers also are found and they are like the female flowers.

There are several species of *Ficus* growing in South

ıdia such as, *Ficus glomerata*, Roxb., *F. religiosa*, L., *'icus hispida*, L. f., *F. asperrima*, Roxb.

Dorstenia indica, Wall., is a small herb growing on the ıills possessing a flat receptacle called coenanthium with ›oth male and female flowers.

Boehmeria nivea yields the well-known silky Rhea ibre. *Cannabis sativa* a dioecious plant yields the in oxicating stuff called **bhang**. The well known Bread-'ruit Tree, *Artocarpus incisa* is cultivated. The hardy *Streblus asper* is a dioecious tree with stamens infolded. Several species of *Pouzolzia* flourish on the hills. *Debregeasia velutina* is a tree of hills.

MONOCOTYLEDONS

Orchideae

Type: *Eulophia virens*, Brown.

This is a common ground orchid of the plains. It is perennial with a large conical pseudobulb. Leaves large, linear, with a midrib and plaited. Inflorescence a long stalked raceme, springing from the side of the pseudobulb. Flowers bisexual, irregular, zygomorphic, with small persistent bracts. Sepals three, greenish. Petals three, green with red lines, the two lateral narrow, and the lower third petal is adnate at the base to the style, saccate at base, three-lobed with the middle larger than the lateral and bearing on the upper surface ridges of thread-like outgrowths. This petal is called the **labellum** or the **lip**. Stamen solitary, reduced to an anther seated on the top of the style. Pollen-grains cohering in masses called pollinia. Each pollinium has a stalk which is attached to the gland. Ovary inferior, one-celled, with three parietal placentas. The stigma is the concave surface of the column below the anther

The fruit is a capsule. Seeds very small with a lax hyaline testa.

This Family is a large one and their members attain their highest development in the tropical forests and live

Fig. 360.—*Eulophia virens.* A plant with its inflorescence.

as epiphytes. Many of the epiphytic forms develop pseudobulbs. Amongst terrestrial forms a great many species have tuberous roots, as in most Habenarias.

On the hills species of the genera, *Aerides, Habenaria, Coelogyne, Dendrobium, Bulbophyllum, Calanthe, Liparis,* and *Satyrium* are common. A few like, *Habenaria viridiflora,* R. Br., H. *platyphylla,* Spreng., and *Zeuxine sulcata* occur in the plains. *Vanda Roxburghii* with its

ng stout aerial roots grows as an epiphyte on the ranches of trees.

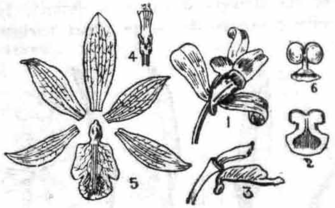


Fig. 361.—*Eulophia virens.* 1, a flower; 2, an anther; 3, style and the labellum; 4, front view of the style; 5, petals and sepals; 6, pollinia.

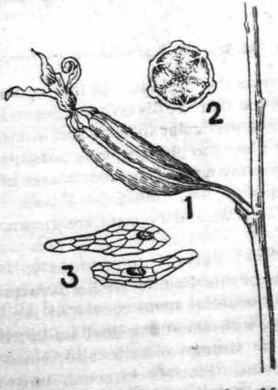


Fig. 362.—*Eulophia virens.* 1, a fruit; 2, section of fruit; 3. seeds.

The most striking feature of orchids is the great diversity in the structure, size and form of their flowers in spite of the flowers being of a definite type. No other Family presents the same great variation in its

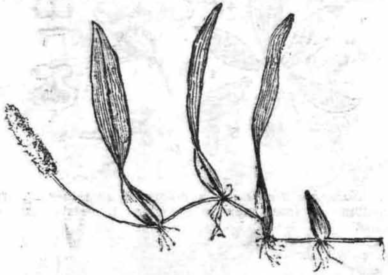


Fig. 363.—*Bulbophyllum neilgherrense.*

flower-forms as the orchids. In this connection it must be remembered that the diversity is due to its adaptation to the visits of particular insects, and if visits of insects do not take place, no pollination is possible.

Orchids are favourites in green houses of cool places. Several species of *Cattleya*, *Vanda*, *Dendrobium*, *Eulophia*, *Calanthe* and *Pogonia* are grown.

Scitamineae :—

The plants of this Family are herbs with rhizomes or stolons, and the aerial stems consist of the leaf-sheaths. Leaves large, with sheathing leaf-stalks; blade usually large with a strong mid-rib and close-set parallel secondary veins. Flowers bisexual, unisexual or polygamous. Sepals three, free or connate. Petals, three,

ee or tubular. Stamens one or five; ovary inferior, three-lled. Fruit a berry or capsule. Seeds arillate and idosperm is floury.

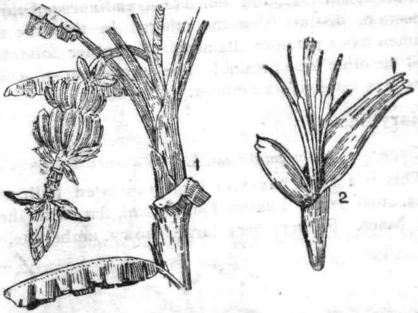


Fig. 364.—*Musa paradisiaca.* 1, top of the tree with fruiting spike; 2, a flower.

Musa paradisiaca, L., may be considered as typical of one section of this large Family. In this plant the flowers are in a fleshy spike which rises from the underground stem. The lower flowers are female, the middle ones bisexual and the upper male. The bracts are large, leathery and spathaceous. The calyx is tubular, slit down on one side and five-toothed. The corolla is reduced to a single membranous petal. Stamens are five.

The Traveller's Tree *Ravenala madagascariensis* often planted in gardens belongs to this section.

Curcuma longa, L., *Zingiber officinale*, Rosc., *Elettaria Cardamomum*, Maton., belong to another section. In all these the flowers are irregular, and there is only one stamen with a completely two-lobed anther; some

staminodes are petaloid. The style passes between th lobes of the anthers. *Hedychium coronarium*, Koen., also of this section.

Canna indica, L., and *Maranta arundinaceae* belong t a section, distinct from the others. In this the singl stamen has a petaloid filament, one anther lobe fertil and the other lobe petaloid. The other petal-like struc tures are petaloid staminodes.

Amaryllideae

Type:—*Crinum asiaticum*, L.

This is a herb having a large tunicated bulb with a long, stout neck. Leaves long, broad, flat with sheathing bases. Flowers very large, showy, umbellate, on a

Fig. 365.—Flower of *Crinum asiaticum*.

stout scape. Perianth tubular, white, six-lobed, lobes linear-oblong. Stamens six with versatile anthers. Ovary inferior, three-celled, with many ovules in each. Fruit a capsule bursting irregularly. Seeds few, large

nd rounded, with plenty of endosperm and without seed-coats.

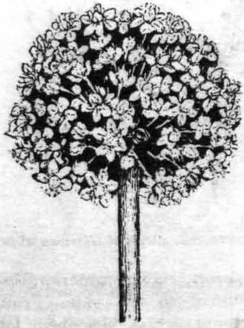
Eucharis candida, Planch., and species of *Pancratium* and *Zephyranthus* are occasionally grown in gardens. *Polyanthes tuberosa*, L. whose flowers are very fragrant is another common garden plant.

Curculigo orchioides, Gaertn., a common species occurring wild in sandy situations and species of *Agave* planted for hedging belong to this Family. These do not have bulbs, but have erect cylindrical stems, covered densely with leaves and without branches.

Liliaceae

Type :—*Gloriosa superba*, L.

This is a climbing plant with large, scarlet, very showy flowers. This plant possesses underground stem-



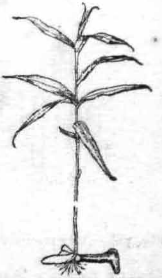


Fig. 367.—A plant of *Gloriosa superba* with its stem-tuber.

Fig. 366.—Inflorescence of *Allium cepa.*

tubers, which have the shape of a country plough (hence the Tamil name Kalappaikizhangu of this plant), and

the aerial branches arise from them. Leaves sub-opposite, opposite or whorled, sessile, lanceolate with the apex drawn out into a tendril. Flowers large, solitary, axillary. Perianth of six-lobes, in two series, petaloid, scarlet; lobes linear-lanceolate with wavy margins and

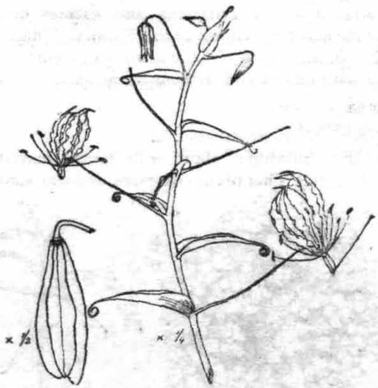


Fig. 368.—A branch with flowers, and a fruit of *Gloriosa superba*.

reflexed, instead of being erect. Ovary superior, three-celled, with the style turned to one side. Fruit a capsule.

This Family is very much like *Amaryllideae* but the ovary is superior instead of inferior.

The garden plants Tulips, Hyacinths, Yucca,

Dracaenas and the cultivated *Allium cepa*, L. (Onion) and *A. sativum*, L. (Garlic) belong to this Family.

The bulbous plants *Iphigenia indica* A. Gray ; *Scilla indica*, Baker., and *Urginea indica*, Kunth., grow in dry sandy places. *Asparagus racemosus*, Willd., grows in low jungles. It has tuberous roots and cladodes arising from the axils of minute scale-like leaves.

Chlorophytum attenuatum, Baker., and *C. tuberosum*, Baker., are met with here and there in the plains. Several species of *Smilax* and *Lilium neilgherrense*, L., with very large beautiful white flowers occur on the hills, at higher elevations.

Commelinaceae

Type :—*Commelina bengalensis*, L.

Fig. 369.—*Commelina bengalensis*. 1, a branch ; 2, a bit of a branch showing an young involute leaf ; 3, cleistogamous flowers ; 4, spathe and inflorescence ; 5, a spathe cut open to show the young inflorescence ; 6, stamens ; 7, young fruit ; 8, old fruits ; 9 and 10, seeds.

This is a dichotomously branching, slender, diffuse herb with creeping branches rooting at the nodes. Leaves alternate, oblong, or ovate-oblong, shortly

stalked with a sheathing base, unequal, involute. Flowers in scorpioid cymes enclosed in funnel-shaped spathes. Sepals three, small, oblong. Petals three, deep blue. Stamens six, three or four perfect, rest staminodes. Ovary superior, three celled; two cells two-ovuled and the third one-ovuled. Fruit pyriform capsule, with five seeds. Seeds oblong closely pitted. This plant produces cleistogamous flowers also.

Several species of *Commelina* occur as weeds. *Cyanotis axillaris*, Schultes., *C. cucullata*, Kunth., are well known weeds of cultivated fields. *Aneilema spiratum*, R. Br., *A., nudiflorum*, R. Br., are common in wet situations.

Palmae

Type:—*Cocos nucifera*, L.
(Coconut Palm.)

This is a tall tree with a straight, unbranched stem, thickened at base, annulate, varying in height from fifty to eighty feet. Leaves are very large with a very long petiole expanded at the base where it clasps the stem, pinnately compound; leaflets are equi-distant, linear, coriaceous. Flowers, unisexual, monoecious, in a branched spike, enclosed by a large spathe. Female flowers, few, large, towards the basal portions of the branches of the spike, and sometimes with a male flower on each side; these are two broad bracteoles. Perianth of three sepals and three petals, all accrescent. Ovary is superior, three-celled. Male flowers have three very short sepals and three oblong petals, both valvate. There are six stamens. Pistillode present or not. The fruit is a fibrous drupe, with a single massive seed, which consists of a huge mass of endosperm enclosing a cavity filled with a liquid (coconut milk) and a small embryo embedded in the endosperm.

Phoenix sylvestris, Roxb., *Calamus Rotang*. L., *Borassus flabellifer*, L., *Areca Catechu*, L., are some of the other palms in South India.

Aroideae

This is a very well defined Family in which the flowers are reduced to their essential organs, the stamens and

Fig. 370.—A plant with corm of *Amorphophallus campanulatus*.

Fig. 371.—Inflorescence of *Amorphophallus campanulatus*.

the pistil, and they are borne by a spadix enclosed by a spathe.

Plants of this Family are perennial herbs, or scandent shrubs, usually with corms. Leaves are alternate with a petiole having a sheathing base; blade is entire or lobed

in various ways. Flowers are uni- or bi-sexual, monoecious. Male flowers towards the apex and female flowers at the base of the spadix, often with neuters between them and sometimes with neuters above the male flowers. Perianth absent. Stamens in male flowers one, in bisexual more. Ovary sessile, three-celled. Fruits berries or drupes.

Amorphophallus campanulatus Bl., *Synantherias sylvatica*, Schott., *Cryptocoryne spiralis*, Fisch., *Pistia stratiotes* L., *Typhonium trilobatum*, Schott., *Pothos scandens*, L., *Theriophonum crenatum*, Bl., and *Colocasia antiquorum*, Schott., belong to this Family.

Cyperaceae

Types :—*Cyperus rotundus*, L.
Fimbristylis miliacea, L.

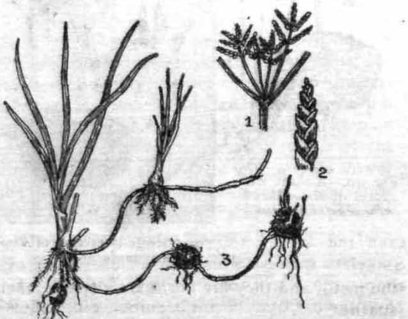


Fig. 372.—*Cyperus rotundus.* 1, inflorescence; 2, a spikelet; 3, plant with tubers and *rhizome.*

Cyperus rotundus consists of underground stolons bearing fragrant tubers and a few aerial branches ending in inflorescences. Leaves tubular, three-ranked, crowded at the base of the stem and grass-like. Inflorescence an umbel of spikelets. A spikelet has ten to fifty glumes distichously arranged and the flowers are in the axils of glumes. Flowers of three stamens and an ovary with a three-fid stigma and without any perianth. Ovary superior, one-celled. Fruit a blackish trigonous nut.

Fimbristylis miliacea, Vahl., occurs in moist places and in paddy fields. It is annual and tufted. Leaves shorter

Fig. 373.—*Fimbristylis miliacea.* 1, a plant; 2, fruit; 3, a spikelet.

than the stem, with sheaths distichously arranged. Spikelets globose with closely imbricating ovate, boat-shaped glu nes, in compound open umbels; stamens vary from one to three. Fruit is an obovoid, yellowish, tuberculate nut. Style three-fid.

Several species of *Cyperus*, *Fimbristylis*, *Scirpus*, *Eleocharis*, and *Fuirena* occur in South India.

Gramineae

Types :—*Panicum javanicum*, Poir.
Eleusine aegyptiaca, Desf.

Panicum javanicum is a common grass with prostrate branches, rooting at the nodes, and geniculately bending upwards. Leaves are alternate, with a loose softly hairy sheath, split open on one side ; the blade

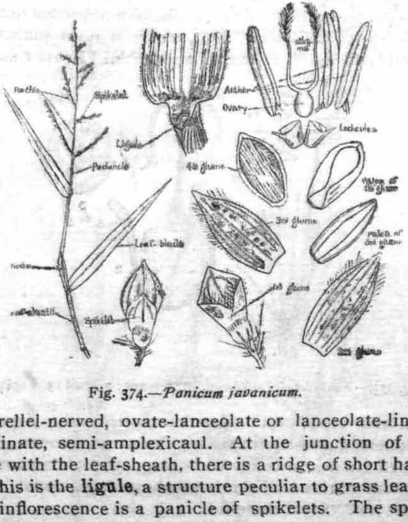


Fig. 374.—*Panicum javanicum.*

is parellel-nerved, ovate-lanceolate or lanceolate-linear, acuminate, semi-amplexicaul. At the junction of the blade with the leaf-sheath, there is a ridge of short hairs, and this is the **ligule**, a structure peculiar to grass leaves. The inflorescence is a panicle of spikelets. The spikelets are bi-seriate, ovoid, with very short pubescent pedicels. The spikelet consists of four glumes ; the first

;lume is very small, broadly ovate, less than half the ɜngth of the third glume, three- to five-veined; the second ; ovate, acute, seven- veined; the third is broader five-eined, paleate, sometimes with three stamens; the ourth is oblong, rugose, tip rounded and with a mucro nd crustaceous palea. The first three glumes empty, he fourth glume alone containing a bisexual flower. nside the fourth glume and its palea two cuneate

'ig. 375.—*Eleusine aegyptiaca.* 1, a branch with ear-heads; 2, a bit of leaf showing the ligule; 3, 4, spikes; 5, a spikelet; 6, glumes, lodicules, stamens and the pistil.

eshy bodies called **lodicules** occur and these are the udimentary perianth lobes. Ovary one-celled, with wo plu nose stigmas. Fruit is a grain enclosed by the ourth glume and its palea.

Eleusine aegyptiaca, is a prostrate annual with tems rooting at the nodes. Stem glabrous and compressed. Leaves linear, glabrous or with a few hairs, and vith a ligule of hairs. The inflorescence consists of four r more spikes borne palmately by a peduncle. Spikelets

biseriate on one side of the rachis ; spikelets five to seven glumed. First two glumes barren, empty and the succeeding paleate and flower-bearing. Lodicules two. Fruit a grain, free.

All grasses, bamboos, cereal plants, sugarcane are members of this Family. The leaves are peculiar. They have a sheathing stalk and this is the hypopodium or base of the leaf well developed, and is not morphologically the equivalent of the petiole.

Several species of *Panicum, Setaria, Andropogon, Aristida, Eragrostis, Iseilema* and *Chloris* grow in South India in the plains.

This Family is the largest of Angiosperms and of much economic importance. All the cereals, the staple food of mankind are Gramineae. Bamboos are of very great use.

CHAPTER XXV

PLANT IN RELATION TO ITS ENVIRONMENT AND TYPES OF VEGETATION

THE main object of systematic classification is to bring out or show the relationship of individual plants and groups to one another, as all plants constituting the flora of the present day have come into existence from pre-existing forms of plants, through the process of evolution. For systematic classification species are viewed as units and the floristic characteristics form the basis for classification. We may also consider the plants from a different stand-point of view. They may be studied with reference to their environment. For example, we may study the plants growing in a certain area of land, and as a result of this it would be found that species of plants belonging to very diverse groups having no relationship whatsoever are growing together. It may be argued with good reason that this association of different species of plants in any particular area is due to mere chance. That this intermingling of species of plants is not due to sheer chance is obvious from the fact that in similar localities we find, more or less, the same group of plants with slight variations if any. In a marshy place in the plains we find species of *Ammannia*, Sedges, *Limnophila*, *Dopatrium*, *Bonnaya*, *Sphaeranthus* and *Moschosma*. In different marshy places we find practically the same vegetation, though there may be variations in the species.

It must be remembered that the form of a plant is

determined by its mode of nutrition, and to a very great extent, this nutrition is dependent upon the environment of the plant. The proper growth and development of a plant in a particular locality is sufficient evidence that there is a harmonious adjustment between the plant and the physical factors amidst which it is growing. All green plants thrive well, if they are able to obtain water, salts, carbon dioxide, oxygen and light. The main external factors of the environment that influence the growth of the plant are water, air, light, and the soil. These factors act on the plant as so many stimuli and the plant responds readily, and this response is functional. So long as the intensity and the amount of *the stimuli do not go above or fall below certain limits,* a plant will grow and develop properly. For every factor there is a maximum, optimum and minimum limit. When the factors are at their optimum limit, they develop very well, and if below or above this limit, the development is not likely to be so good. Generally the maximum and minimum limits of the chief factors are not close, but far apart and, therefore, plants growing under normal conditions are able in many cases to prolong their lives even when these conditions have undergone modifications in one direction or other; and, if they possess the power of adaptation to changed conditions, they manage, at first, to live somehow, and later on they get well established. Plants that cannot adapt themselves to the factors of their environment, when such factors change, become extinct.

A vast majority of plants containing chloroplasts are self-supporting or autotrophic in their mode of life. They are structurally best adapted for this kind of life and hence they may be considered as normal plants. Amongst flowering plants we find plants like *Loranthus*

and *Viscum* growing on the branches of trees such as the tamarind, the margosa, the mango and *Pongamia*. The leaves and young twigs of *Loranthus* and *Viscum* are quite green like the leaves and twigs of the trees upon whose branches these are growing. These plants are dependent upon the trees for the supply of their water and salts. The roots of these plants instead of getting into the soil attach themselves to the stems of other green plants by means of suckers or haustoria. In *Viscum* the external attachment is in only one place, though internally it may penetrate in all directions along the cambium. *Loranthus*, on the other hand, attaches itself externally to the branches of the host by a number of haustoria. The haustoria or sucking organs penetrate the bark of the branches of the host and become intimately connected with the inner woody tissues of the branches of the host. It is this intimate connexion between the wood of the parasite and the host that enables the former to obtain water and salts passing through the stem of the latter. Although these plants are dependent upon other green plants for water and salts, they are able to carry on the work of photosynthesis and, therefore, these are partial parasites.

Amongst flowering plants, there are also partial parasites that obtain their supply of water and salts from the host-plants by attaching themselves to their roots, instead of stems. For example the Sandalwood tree, the shrubs *Cansjera Rheedhii* and *Ximenia americana* and the herbs *Striga lutea*, *Sopubia delphinifolia*, *S. trifida* and *Pedicularis zeylanica* are partial parasites attaching themselves to the roots of their host plants.

Some flowering plants are dependent on their host, both for inorganic and organic substances and water. These are complete parasites. The species *Balanophora*

Fig. 376.—*Balanophora indica*

indica is a common parasite growing attached to the roots of trees or shrubs. The whole plant is white, without any green colour. Hence all the food supply must be obtained from the host plant.

The twiners, *Cassytha filiformis* and *Cuscuta chinensis*, both leafless and consisting of cylindrical stems secure attachment with the stems of green plants by means of haustoria, and live as complete parasites. In most of the flowering parasitic plants, the vegetative part gets degenerated and reduced to its minimum. But the part intended for reproduction, the flower, is well developed, and as a matter of fact the parasitic plant *Rafflesia* usually parasitic on *Cissus* consists chiefly of a huge flower.

All the flowering parasitic plants have special adaptations for the dispersion of their seeds. The species of *Striga*, *Orobanche* and *Christisonia* produce seeds in abundance. A *Striga* plant produces about 60,000 small seeds. Species of *Viscum* and *Loranthus* also have a large number of seeds. These fruits are edible and sticky and, therefore, birds pick these fruits and, as the seeds stick on to their beaks, they get rid of them by transferring them to the twigs and branches of trees.

Fungi as a class are heterotrophic plants, and in many ways they are one of the most remarkable groups of plants. Though the vegetative parts of the Fungi are simple, their power of adaptation to varying conditions and the way they affect their hosts are things to be wondered at.

The class of plants called Lichens found growing on rocks and barks of trees are rather interesting plants. Every Lichen represents a combination of a Fungus and an Alga growing together and there is mutual help bet-

ween these two in the matter of nutrition. The Fungus part of the Lichen absorbs water and salts for the use of both the fungus and the Algae, and the Alga prepares carbohydrate material for its own use as well as for the Fungus.

In the case of some flowering plants, we find in the younger parts of their roots a closely woven sheath of fungal hypae instead of root-hairs. Some of the hyphae protrude like root-hairs. These sheaths of mycelial hyphae covering the roots of flowering plants are known as **mycorrhiza.** Trees such as the Beech, Hornbeam, Oak and Scots Pine have mycorrhiza in the root-systems. The absorption of water and salts is done by the mycorrhiza, and the mycorrhiza derive the organic food material from the roots of the trees. This mutualism is similar to that of Lichens.

In some plants the fungal hyphae seem to live inside the roots of plants and help them to get not only water and salts but also some amount of organic material. This kind of endotrophic mycorrhiza is common in some orchids (such as *Neottia* and *Corallorhiza*) and in the prothalli of *Lycopodium* and *Ophioglossum*.

The normal method of obtaining the nitrogen necessary for proteid formation is from salts containing nitrogen. Some flowering plants, however, seem to supplement this by taking in organic nitrogenous substances by special contrivances from insects. The insectivorous plants *Drosera indica. D. Burmanni* and *Utricularia flexuosa* flourishing in South India are plants of this kind. The leaves of *Drosera* are covered with bristle-like hairs ending in glandular tips. If an insect settles on the leaf it gets caught amidst these glandular hairs, since a sticky juice is secreted by the glands at the tips of the hairs. As soon as the insect alights on

the leaf the hairs curve inwards so as to entangle the insect. The juice secreted contain ferments capable of digesting the organic substances of the insect. *Utricularia* or bladder-worts flourish in water or marshy places.

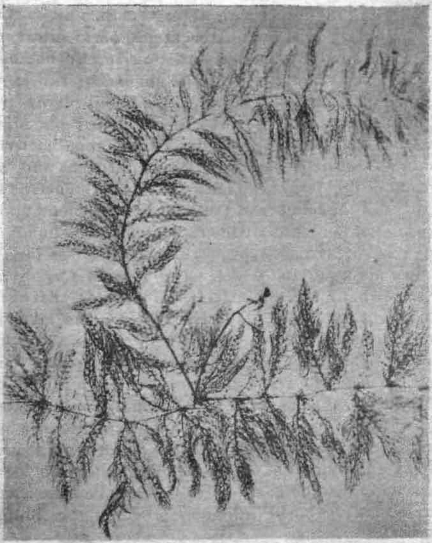


Fig. 377.—*Utricularia flexuosa*. The black dots seen in the leaves are all bladders.

They have a large number of bladder-like structures in their leaves. Every one of these bladders is provided

with trap-doors opening into the cavity of the bladder and insects are drawn into the bladders and they are later digested. The trap-doors have bristles that are sensitive to the stimulus set up by the insect or water and so, when an insect or water rushes past the trap doors, they open and the insect with water gets in.

Leguminous plants obtain the atmospheric nitrogen, through the agency of bacteria existing in the nodules found attached to their roots. The nodules or tubercles developed on the roots of all the Leguminous plants are full of bacteria and abnormally-developed bacterial masses called bacterioids. In the first instance bacteria infect the root-hairs and then invade the roots and, as the result of this inroad, nodules are formed. The shape and size and the number of these tubercles depend upon the species of the plant. Bacterial nodules are abundant in the roots of *Arachis hypogaea* and *Crotalaria juncea* and they are small and round. The roots of *Cyamopsis* bear somewhat larger lobed bacterial nodules. Between the bacteria and the plants bearing them in the nodules there appears to be some mutual help in the matter of nutrition. The plant makes use of the protein food which the bacteria make by using the free nitrogen of the air, while the bacteria live on the carbohydrates supplied by the host plant. As long as the bacteria are alive, the host plant gets a steady supply of nitrogenous material, and by reason of this peculiar mutualism leguminous crops can be grown in soils which contain small quantities of combined nitrogen, provided the proper bacteria are present.

Other plants besides leguminous plants bear the bacterial nodules in their root-systems. The roots of the plants *Elaeagnus* and *Alnus* have bacterial nodules and so they are also able to utilise free atmospheric nitrogen.

All plants are capable of adjusting themselves to temporary changes in their environment, provided such changes are of short duration. So long as the stimuli are normal and of ordinary intensity, responses on the part of the plant consist in mere normal adjustments that are necessary for their ordinary activity. For instance, any change in the air or in the daylight may cause change of position in the case of the leaves of the plant. When the light becomes intense and the air dry, the leaves of many plants assume a vertical position from the usual horizontal position. As soon as these adverse conditions pass off, the leaves resume their normal horizontal position. If, however, the dryness of the air and the intensity of light become continuous without returning to their original normal conditions, the adjustment on the part of the plant must become most pronounced, and there will also be certain structural changes. So, whether a plant responds by ordinary adjustment only or along with structural changes depends upon the nature of the stimulus. When the stimulus is of ordinary intensity and temporary the plant responds by its usual functional adjustments, without any change in structure. If, on the other hand, the stimulus is of unusual intensity or continuous the response on the part of the plant is an adaptation, that is to say, an adjustment coupled with some structural modifications.

The chief factors that influence the plants, namely, water, light, heat, soil, associated plants and animals, do not act singly, but many of them act simultaneously. The general character of the vegetation over wide areas is determined by the climate. The climate of a place is dependent upon the factors, rainfall, sunshine, temperature, the force and direction of winds, whose charac-

teristics are determined by the geographical position and altitude. An area, over which rainfall is well distributed and in which the soil is capable of good drainage, will usually be covered with good vegetation. A profusion of vegetation will be the result, if there be good sunshine in addition to rainfall and drainage. In the absence of rain, although other conditions may exist, the growth of plants is poor and even those that grow would be very much stunted. The character of the

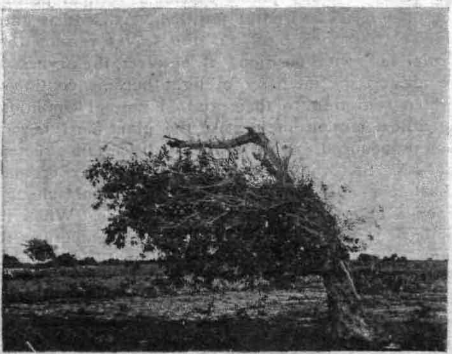


Fig 378.—A *Ficus* tree exposed to wind.

wind exerts a profound influence on the general aspect of the vegetation. For example, in higher altitudes or on the plains, situations that are exposed to constant winds look bare and support only very low plants such as grasses and other herbs. Even if there be trees they are only very few occurring here and there. On

close examination, it would be found that trees growing in such exposed situations are wind-swept and lop-sided in growth, or they become stunted. (See fig. 378.) Trees flourishing under such conditions are low in stature, and the trunk and the branches and the boughs are bent in the direction towards which the wind blows and the branches are interlaced. On the wind-ward side no branches are developed, but they are abundant on the lee-side. The crowns of trees look as if clipped and rounded off on one side.

As already stated, the general appearance of the plant, its structural features depend to a very great

Fig. 379.—*Rhododendron* trees growing on exposed grassy downs on higher elevations of the Nilgiri Hills.

extent upon the influence exerted by the factors of its environment, and these factors affect mainly the vegetative organs to a marked degree. The flowers which are the reproductive organs are not at all affected directly by these factors.

The ecological factors influencing the growth and development of plants are not few and their combinations are many. Consequently the ecological groups of plants also must necessarily be many. Since these sets of factors impress their marks on the plants, we should naturally expect all plants subjected to the same set of factors to have some striking characteristics of the same sort, although the plants may be of different Families. For example the aquatic plants *Nelumbium speciosum*, *Limnanthemum indicum* and *Trapa bispinosa* have the same kind of structural adaptations in their vegetative organs, though they belong to widely separated Families. The submerged aquatic plants *Ceratophyllum demersum* and *Hydrilla verticillata* are alike in their vegetative parts and have similar adaptations. The three species of plants, namely, *Euphorbia antiquorum*, *Opuntia Dillenii* and *Boucerosia umbellata* growing in very dry situations and belonging to three distinct Families have the same type of vegetative shoots. The same kind of structural modifications caused by a set of ecological factors, in diverse species of plants, genealogically wide apart, is generally termed a **growth-form**. For ecological classification growth forms may be taken as units. The growth-forms seen in *Euphorbia antiquorum* and *Boucerosia umbellata* are quite characteristic of plants growing in very dry places. Since the combinations of factors are many, the number of ecological groups of plants are also large. But we shall deal with only the most striking types of vegetation.

Hydrophytes :—Of the various factors that influence plants water exercises the greatest influence. Differences in the supply of water exert a profound influence on the growth and development of vegetation. From every day experience one can easily gather that an adequate supply

of water yields a richer crop of plants and, if the supply of water is poor, the growth of plants is affected and stunted plants result. Many of the vital functions of plants are dependent upon water. Further, all other factors such as wind, light, soil etc., influence the plants only through their action upon water.

The form and structure of a plant is affected to a greater extent by water than by any other factor. How very far-reaching is the influence of water on the structure and form of plants can be gathered when we compare a submerged aquatic plant with a land plant. The aquatic plants *Hydrilla verticillata* and *Ottelia alismoides* become limpid and are incapable of remaining erect when lifted out of water. All submerged aquatic plants become flaccid when taken out of water, because they do not contain xylem and other such tissues which give rigidity to the ordinary land plants. The conditions obtained under water are more or less uniform and, consequently, all submerged aquatic plants are alike in several respects. The supporting and conducting tissues, so very essential in the case of land plants, are superfluous in the case of submerged water plants. As these plants are in contact with the water, at every point externally, the whole surface of the plant is available for the absorption of water. The weight of the plant is supported by water. Further the air-cavities, so characteristic of aquatic plants, are full of air and these help in flotation. As oxygen dissolves in water but sparingly, aquatic plants are at a disadvantage in obtaining oxygen freely, compared with plants whose medium is air. So aquatic plants should have special means to obtain oxygen in sufficient quantities to carry on respiration. This special means is the development of air spaces in their stems and leaves.

Amongst submerged water plants some are fixed to a substratum and others are free swimming. Many of the species of the Family Hydrocharideae grow fixed to the soil at the bottom of the pond. Algae are attached to the stems and branches, or to stones. Leaves of submerged aquatics are usually thin and delicate. They also vary in their shape and size. Plants that are

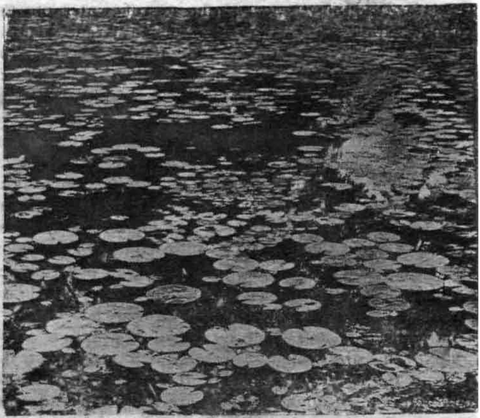


Fig. 380.—*Nyhmphaea pubescens.* A floating aquatic plant.

thriving in still water usually possess fairly large leaves. For example, the species *Ottelia alismoides* grows abundantly at the bottom of ponds and tanks in which water is not subject to much of motion, and the leaves are

broadly ovate and large. We find in the plant *Vallisneria spiralis* long linear strap-shaped leaves and this plant thrives well in situations under water wherein the water is subjected to much of motion caused by winds.

Fig. 381.—*Neulmbium speciosum*—An aquatic plant with leaves elevated above the surface of water.

As examples for floating plants we may mention, *Ceratophyllum demersum*, some species of *Utricularia*,

and the Algae, *Spirogyra* and *Cladophora*. These plants are carried about freely in water.

There are also aquatic plants whose leaves alone float on the surface, as in *Aponogeton*, *Nymphaea* and *Trapa*. The leaves of all these plants are somewhat thick, and waxy on the upper surface. Stomata are found only on the upper surfaces of these leaves. In *Nelumbium* the leaves are often raised above the surface of water. The parts submerged under water have air-spaces and are spongy in structure.

Compared with the land plants, aquatic plants have certain advantages favourable to growth. The aquatic mode of life favours the easy absorption of water and plenty of it is available. Sufficient quantities of carbon dioxide, oxygen and inorganic salts are at the disposal of the aquatic plants. Thus favoured, these plants can grow very rapidly, multiply and extend very quickly, by means of vegetative reproduction. The abundance of food material favours the growth of the vegetative organs to a greater extent than the sexual organs. So in aquatic plants vegetative multiplication far exceeds the sexual reproduction, and some species, such as *Elodea*, *Lemna*, multiply solely by vegetative propagation. Many aquatic plants possess the power of vegetative propagation as well as the method of sexual reproduction. Plants such as *Vallisneria*, *Hydrilla* and *Ottelia* develop flowers and these come up to the surface of the water for pollination. The female flowers are borne on long stalks and so they come up to the surface of water when they are ready for pollination. Male flowers get detached and float in large numbers, which must necessarily bring about pollination.

Some plants flourishing in water are amphibious in their mode of life and so they are able to grow very

apidly and occupy large areas and become pests. For xample the aquatic plant, *Eichornea crassipes* which vas introduced as a thing of beauty, has run wild and is ow found everywhere in South India. No doubt the lower spikes are exceedingly pretty and attractive, but ts spread is so rapid and it covers the surface of the vater so completely, as to make it a very bad weed. When nce this plant finds its way to a tank or pond, it cannot asily be removed, on account of its quick growth and evelopment.

We find a large number of plants adapted to thrive in narshy places. In such plants a portion of the shoot-ystem is submerged and the remaining portion is aerial. 'he aerial portion of the shoot bears leaves which differ ery much from those that are submerged. Like sub-nerged plants, plants growing in marshy places cannot btain oxygen in adequate quantities. Of course marsh-lants are better off than submerged aquatic plants, ecause some portion of the shoots are aerial. Even in uch plants the root-systems cannot obtain the necessary xygen from the slushy soil. To enable the root-systems o obtain enough air containing oxygen, such plants evelop breathing roots or pneumatophores. We have lready spoken about these special roots. (See pages 7 and 48). Even herbs growing in water develop ect roots which thrust their tips above water. Such lants are species of *Jussieuea*. (See fig. 382). In some narsh-plants, in addition to the air spaces in the stems, a pecial tissue called aerenchyma is formed from the hellogen layer in the stems or roots. The spongy hite tissue found in the internodes of *Neptunia oleracea* nd in the roots of *Jussieuea* is aerenchyma. These hite spongy masses in the parts of plants help in the oatation.

Ordinary land plants obtain their water from the soil, wherein it exists as thin films adhering to soil particles. So long as there is an adequate supply of water in the soil, these plants grow very well. When plants are ensured of a liberal and uniform supply of water, they

Fig. 382.—Breathing roots of a marsh-plant *(Jussieuea)*. Note the rows of breathing roots whose bent tips have come up to the surface of water.

develop leaves with thin blades and soft less woody parts, without any protective tissues. Plants growing in moist forests are of this kind. In all tropical forests having a heavy rainfall, great luxuriance of vegetation is the prevailing condition. All plants thriving in a soil of moderate humidity are called **mesophytes**. These plants occupy an intermediate position between aquatic plants on the one hand, and those growing in very dry places or **xerophytes** on the other. In the flora of South India the mesophytes constitute the average

vegetation, although special types of vegetation also occur here and there.

Xerophytes:—We know that land-plants obtain all the water from the soil through their roots from the soil. Since water is being absorbed continuously, there is a regular flow of water from the roots to the leaves through the stems. Leaves are constantly transpiring and, as a matter of fact, the structure, position and arrangement of leaves are such as to facilitate this process. So long as the absorption of water by the roots and evaporation of it from the leaves are equal, the plant is not affected. If the water in the soil entering the roots becomes less than the transpired water, then plants suffer. On a hot day the general wilted condition of the crop plants in a field illustrates this point very well. In moderately dry places, as a rule, plants bring about certain adjustments to lower the rate of transpiration. The shifting of the position of the leaves, the rolling inwards of the leaves of grasses are some of the means adopted by plants to lessen transpiration. If the period of dryness is only short, beyond this temporary adjustment there will be no other change in the plants. On the other hand, plants growing in places where there is a prolonged drought get modified in various directions, and although these plants belong to widely different families they become remarkably similar, and we get definite growth-forms.

Where rainfall is scanty the soil is without much water. The physical texture of the soil and the temperature have marked influence. The nature of the soil may vary, but it is always rich in nutriment. Since the soil is dry, this nutriment cannot be absorbed by the roots of plants. Owing to this circumstance the number of plants thriving must be considerably small and

even the few plants that thrive would be stunted in growth.

Even in dry situations conditions for growth may become favourable during a short time in a year. Within this short period many herbs may grow, produce seeds and die. In the case of these annuals, adaptation consists in the brevity of their existence. If the plants that are growing are perennial, the adaptations must be

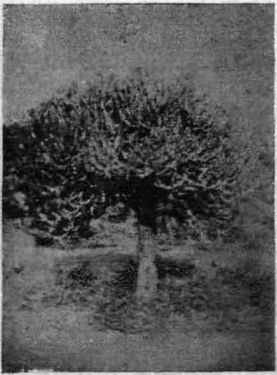


Fig. 383.—*Euphorbia antiquorum.* A fleshy xerophyte.

morphological or structural. Wind, deficiency of water and strong transpiration bring into existence plants with bowed branches, crooked and shortened stems. In most plants we find stunted growth and dense branching. These characteristics help to prevent the

transpiration considerably. In scrub jungles shrubs are mostly of this type.

The growth-forms seen in *Euphorbia antiquorum, Opuntia* and *Boucerosia* are also due to dry conditions. These plants are plump in form and their stems are green, and so they can carry on photosynthesis. Leaves are absent and the epidermis is strongly cuticularised. Stems do not contain much of xylem or other hard tissues, but are provided with a water-tissue and parenchyma that contain plenty of mucilage. Such succulent plants as these are characteristic of situations in which the climatic conditions are periodic, very hot and dry.

The succulence may be in the stem or in the leaves Aloe, *Agave, Echiveria*, and *Portulaca*, have succulent leaves. As examples of succulent-stemmed plants we may mention *Boucerosia, Opuntia, Mamillaria* and some species of *Euphorbia*. The pseudobulbs of epiphytic orchids also come under this category. The increased osmotic power of the roots due to the high temperature of the soil and the supply of nutriment in alternately strong and weak solutions appear to be responsible for succulence in the plants mentioned above. All succulent plants are perennial and long-lived. They can store a large amount of water which they give up extremely slowly and they, therefore, dry only with great difficulty.

We have in plants such as *Indigofera trita, Acacia arabica* and *Odina wodier*, another type of xerophytes. All these plants have deep roots and contain much of lignified tissues. In most of these xerophytes the wood is hard, strong and brittle. Lignification seems to be greater in drier habitats. The cortex is usually narrow and the amount of sap also is not much. Leaves are usually smaller and in some plants other devices for

checking transpiration may also be present. Bark i formed and some resinous material also may be presen in the cortex.

In all xerophytes we find adaptations to minimis transpiration.

Halophytes or plants growing in saline soil :—Th backwaters, the salt swamps and saline flats on botl the East and West coasts support a fairly large amount o vegetation. The land in close proximity to the sea anc at the mouths of rivers and backwaters get submergec daily by the tide and will be exposed only at low water The soil in these situations consists of clay or clay anc sand saturated with water and reeking with foul odour on account of decaying organic matter. Even such a soi as this supports vegetation of a particular type, callec " Mangrove-formation."

The mangrove-vegetation is very common in muddy places where the water is calm. If these muddy swamps are extensive, the mangroves form a low forest. The trees are mostly low with countless arched aerial roots In places, where there is deep water, species of *Rhizophora* grow, as they can fix themselves firmly in deep water. *Avicennia officinalis, Bruguiera gymnorrhiza* and *Aejiceras majus* occupy the shallow places and somewhat dry ground. As the mud in which these plants are growing is soft, fixation is a difficult matter. So in all these trees and shrubs, crooked, arched prop-roots are freely formed. The prop-roots and their tendency to go deep help the mangrove-plants to resist the bending that may be caused by winds and waves.

The soil is always water-logged and poor in oxygen and so respiration is a matter of difficulty. The submerged parts have large air spaces, and these intercellular cavities are in communication with large

stomata and particularly large lenticels. Special respiratory roots also are developed in some species. In *Rhizophora* the prop-roots serve as respiratory roots. The respiratory roots are particularly well developed in

Fig. 384.—Mangrove plants. *Acanthus ilicifolius* in the foreground and *Bruguiera gymnorrhiza* in the back-ground.

the roots of *Avicennia*. The pneumatophores are erect, about a foot or more in length, and stand in radiating rows all around the tree. From the vertical roots the

position and direction of the underground normal horizontal roots may be inferred. (See figs. 32 to 34.)

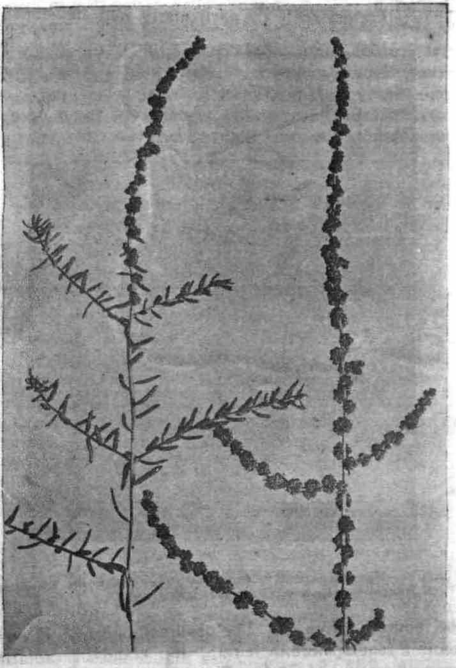


Fig. 385.—A *Suaeda* plant with terete fleshy leaves.

As the water is full of salts, free absorption of water r the roots is out of the question. Plants take up water ıly in small quantities. Further they must also have laptations to prevent undue evaporation. So, in spite of e abundance of water, these plants have in their shoots ructural features characteristic of xerophytes. The aves of many of the mangrove-plants are thick, coriaous, fleshy and the epidermis is strongly cuticularized. ıe chlorenchyma of the leaves consists mainly of ılisade parenchyma without intercellular spaces.

ʒ. 386.—Vegetation on sandy soil. *Hydrophyllax* in the foreground ınd *Ipomoea* in the background.

Vivipary, or the germination of the embryo and its velopment into a seedling within the fruit, while it is ll attached to the parent plant, is a normal condition many mangrove-plants. In *Bruguiera* and *Rhizophora* e embryo grows out of the fruit and remains attached til it develops into a fairly large seedling with a clubaped root-end. The seedling when formed and ready

to drop down into the mud consists of a club-shaped radicle with lateral roots and a hypocotyl with a short shoot (See fig. 17). When the seedling detaches itself it is fairly large and the club-shape and the pointed end of the radicle enable it to pierce the mud. If the seedlings happen to fall on water, they float and get stuck in holes at the earliest opportunity.

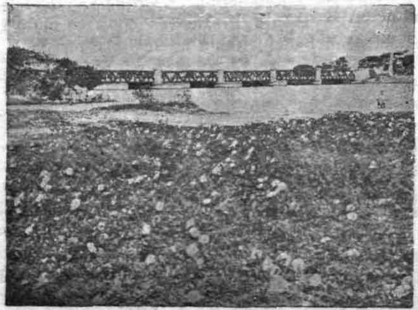


Fig. 387.—*Ipomoea biloba* growing on sand in the beach.

The littoral plants have a very wide distribution and the mangrove swamps have more or less the same species all along the sea-coast throughout the world. This is because of the uniformity of the medium and the temperature existing in the coast. The fruits and seeds of many of these plants of mangrove swamps have special devices to enable them to float. The fruits abound in air-containing spaces and the germinating capacity of the seeds does not get impaired by the saltwater.

Close to the mangrove swamps on the land side, w

ieet with shallow water and flats with mud, moist or ry. The plant *Acanthus ilicifolius* grows in abundance ı shallow places. Here and there we find *Pandanus* fting its head from amidst *Acanthus*. Further away a flats that are distinctly saline we meet with several pecies of *Suaeda, Salicornia, Sesuvium Portulacastrum,* nd *Heliotropium curassavicum.* All these plants are ither herbs or shrubs with pronounced succulence, characteristic of certain xerophytes.

As we recede towards the interior, we find sandy oil with sand-dunes. Sand being loose, the amount of vater that it can retain is small. The loose nature f sand does not permit the rise of water from the ubsoil to any appreciable extent. On account of its eing exposed to the heat of the sun and to wind, the and gets heated rapidly and becomes dry very quickly. o plants fitted to thrive in this sandy soil assume haracteristic growth-forms. The vegetation flourishng on this sand is usually much open. It consists of erennial plants with deep-seated, freely branching hizomes bearing exceedingly long roots. All the plants isplay the xerophytic characters to a marked degree. 'he flora consists of species, such as *Cyperus arenarius, aunnaea pinnatifida, Spinifex squarrossus, Ipomoea iloba, Hydrophyllax maritima, Calotropis gigantea* and *'upalia orbiculata.* Towards the interior this gradually ets merged into the ordinary scrub-flora.

Lastly we have one more group of plants that are eculiar in their mode of life, namely, the **epiphytes.** ıll epiphytes attach themselves to other plants by ieans of aerial roots, but without abstracting anything 'om the latter. Attachment is only for fixation and ıpport. Because of their unusual position they canot obtain the nutriment and water easily. But they

Fig. 388.—*Spinifex squarrosus*, growing in sand.

ve managed to overcome this difficulty in a variety ways. For example, many of the epiphytic :hids and aroids growing in South India possess

Fig. 389.—*Spinifex squarrossus.*

ıerial roots specially adapted for the absorption of vater. These aerial roots are white in appearance ›wing to the formation of a kind of sheath consisting of

several layers of empty cells strengthened with thickenings here and there. This sheath is called **velamen** and it acts as a sort of sponge in absorbing water rapidly; whenever there is rain. Since epiphytes have to endure prolonged droughts like land xerophytes, certain structural features, distinctly xerophytic, are found in these plants. Most of the epiphytic orchids have fleshy

Fig. 390.—The epiphytic orchid *Bulbophyllum* on the trunk of a tree.

pseudobulbs, and in some leaves are thick and fleshy. Arrangement for storage of water is also a necessity, as the sources of supply of water for epiphytes are dew, mist, or rain. The supply of water is precarious and it is possible only at long or short intervals. So these

plants should also have arrangement to prevent the loss of water.

From what is said above, it is obvious that epiphytes cannot live in places where the climate is very dry; but they can live where the atmosphere is likely to be humid

Fig. 391.—Epiphytes growing on the branches of *Ficus religiosa.*

at least for some months. On the East coast of South India we do not find many epiphytes, but, on the other hand, they are found in profusion on the West coast, because humidity is greater and of longer duration in this coast than on the East coast. The illustration in fig. 391 shows a peepul tree abounding in the epiphytes *Vanda Roxburghii,* and *Dryuaria quercifolia.*

Generally epiphytes retain their mode of life throughout their life-cycle. But a few adopt the epiphytic mode of life only in the beginning and later on their

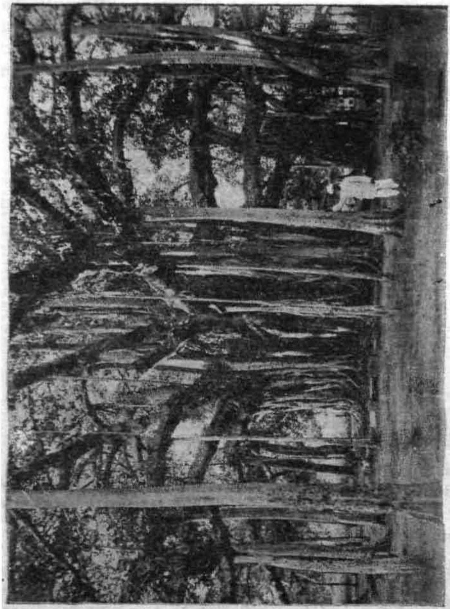


Fig. 392.—Banyan (*Ficus benghalensis*) tree with prop-roots.

oots enter the ground and become ordinary land roots. *Ficus benghalensis* begins its life as an epiphyte, but when it grows large the aerial roots penetrate the soil ınd become supporting roots. The prop-roots help this ree to extend and occupy large areas.

The vegetation of South India is most varied and nteresting. Thick forests with tall trees are confined o the higher hills of the Western ghats. The Deccan-plateau supports scrubby jungles and deciduous forests. n the sea coast in the sand we find sand-binding Kerophytic plants such as *Spinifex squarrossus*, *Ipomoea biloba* and *Hydrophyllax*. This is succeeded by the nangrove swamps in which "mangrove formation" thrives at its best.

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N.B.—The thicker numbers refer to figures.

ERRATA

	Line	for	read
7	9	**Spematophyta**	**Spermatophyta**
12	3rd line under Fig	sitpule	stipule
13	1st line under Fig	Flowers	Flower
52	11	tendencies	tendency
64	11	*paradisica*	*paradisiaca*
82	1	*Etytraria*	*Elytraria*
85	11	*rnncinata*	*runcinata*
12	20	filament by	filaments, each by
22	11	G (2)	G (2)
59	1st line under Fig	seeds	seed
67	17	*hispidulum*	*hispidum*
72	9	protoplasm	protoplasts
78	24	occuring	occurring
89	2	more less	more or less
12	16	root-bearing	root bearing
14	2nd line under Fig	calls	cells
14	8	hte	the
25	6	legumionous	leguminous
77	13	leads	lead
83	under Fig	—N (last)	Nor sol.
86	20	in	is
92	19	Concentrations	Concentration
02	8	enzme	enzyme
15	1	carbon, dioxide	carbon dioxide and
17	16	*gigantia*	*gigantea*
57	1	**combination**	**combinations**
84	2nd line from bottm.	vescicle	vesicle
33	12	*Gleichienia*	*Gleichenia*
55	6	Bryophata	Bryophyta
88	4	*Rannales*	*Ranales*
,	21	*Componulatar*	*Campanulatae*
16	13	*Coccina*	*Coccinea*